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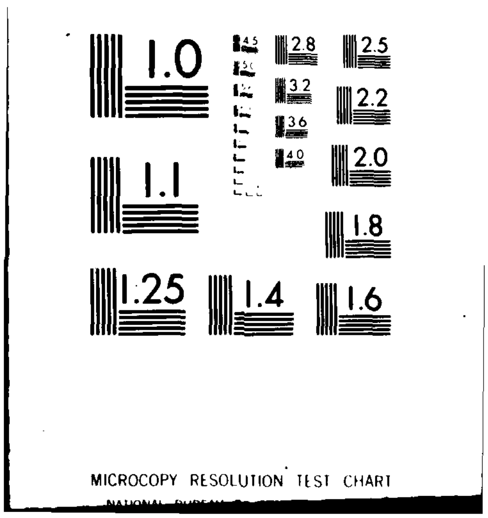
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On Skill Acquisition in Multi-Player Game

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DSI-80-401-2

FINAL REPORT

CONTRACT NO. F49620-80-C-0054

Prepared for:

Air Force Office of Scientific Research
Building 410
Bolling Air Force Base, DC 20332

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a computer program for the off-line simulation of air-to-air combat wherein a friendly aircraft engages two hostile aircraft. The method is based on the Adaptive Maneuvering Logic which is described elsewhere.

The approach selected was influenced by these concepts. (1) The best defense is a good offense. (2) If the friendly is on the offensive against a hostile and does not fly as

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aggressively as possible, the hostile may very well be the victor regardless of what the second hostile does. In the approach the different possible engagement configurations were divided into ten classes and within each class criteria was set up to determine which hostile to engage. A monitor subroutine was developed to determine the appropriate engagement class and hostile to engage.

Twenty-four criteria were developed for scoring the trial maneuvers so as to choose the most optimal one, the one with the highest score. (Rules for computing the value of each criterion relative to the situation were developed.) Each class-hostile pair had a set of weights for the criteria with the score being the sum of the products of the weights and the corresponding criteria value.

The hostile flight paths were fixed scenarios. Each hostile flew a figure 8 with constant speed and altitude and 3g turns. One hostile's path was TIMEH2 (input value) seconds ahead of the other and offset so as not to overlap.

In developing the one-versus-two offline program, many engagements with various initial conditions, with two different types of friendly aircraft (F-4 and F-14) and for various durations were simulated. Ground trace plots for four of the engagements are scheduled in the report.

In general, the maneuvers by the friendly appear to be reasonable ones, although it is difficult to analyze the engagements since the hostiles are noninteractive. For example, the aggressive pilot in engagement two had a decided advantage over the conservative pilot of engagement one at time 30 seconds. On the other hand, at 23 seconds he was vulnerable to an offensive move by hostile 1 in an interactive environment. The last two examples illustrate the result of different aircraft capabilities. The higher performance F-14 had a definite positional advantage over the F-4 at the end of the engagement.

INTRODUCTION

To succeed in aerial combat the pilot must fully understand the developing situation. He must be conversant with the dynamics of his own aircraft and have appreciation for the capabilities of the enemy aircraft.

But, more important than this, he must clearly understand the mission he is to perform, that is, the relative worth (and risk) associated with each of the different degrees of achievement. He must also properly interpret enemy maneuvers in terms of their intent, (similarly expressed in the worth and risk of their achievement).

Although aerial combat remains largely an art, steps have been taken toward making it a science. The pilot is provided extensive instructions as to the dynamics of his aircraft and those of prospective threats. He is given a detailed mission and informed about prospective enemy assignments. He is given "combat experience" in ground-based simulators and more realistic airborne "engagements" against friendly pilots who pose as adversaries. But, such simulation is limited in terms of the diversity of situations the pilot can encounter, of the adversaries he may face, and even of the simulated enemy doctrine his "friends" may adopt.

In recent years, computer simulation of aerial combat has attempted to provide additional "experience." Early programs derived minimum time or energy flight paths given the enemy's trajectory. But such programs omit the most important aspect of combat . . . the enemy is intelligently interactive. Later, heuristic programs such as TAC-AVENGER provided effective simulation of either pilot so long as the aircraft were those of combat experience. But each new aircraft opens the door to new tactics. It is dangerous to fly a F-14 or F-16 against a MIG-15 as if it were an F-4 . . . and even more dangerous to fly these new planes in the old manner against a future threat aircraft. TAC-BRAWLER is now used to simulate m on n aerial combat. However, this program fails to reference the specific intent of each pilot. It is deficient in that the nature of the combat must reflect the particularities of the mission. Given the same situation, the pilot will maneuver differently depending on his mission.

The Adaptive Maneuvering Logic was the first computer program to meet this challenge. Here the purpose of each pilot is made explicit (expressed in quantitative form). The developing situation is interpreted in the light of these purposes so that alternative moves can be evaluated relative to one another. Each second the program adopts the best of these while searching for a suitable move for the next second. Since it is impossible to explore all possible moves at each point in time, it is most productive to evaluate the few most reasonable alternatives and adopt the best of these.

This is exactly what the qualified fighter pilot attempts to do . . . but the computer can evaluate more alternative maneuvers per second and with greater accuracy and precision. As a result, the Adaptive Maneuvering Logic can be used to develop new tactics for present or prospective aircraft, to evaluate prospective aircraft weapon systems and the pilots who will fly these, and for training our present pilots (by comparison of actual inflight maneuvering with those recommended by the AML program including a printout of those situations wherein the program recommended maneuvers significantly better than those taken by the pilot). A notable contribution toward this end has already been demonstrated.

It is generally recognized that two-on-one situations are significantly more difficult for the single fighter than the one-on-one encounter. Here, the first enemy aircraft tries to force the friendly into evasive maneuvers that make him highly vulnerable to the second enemy aircraft. In essence, the enemy conspire to attack concurrently or to force the friendly to accept unfavorable initial conditions for dealing with the second enemy pilot . . . and this works well unless the friendly is capable of taking both enemy aircraft into account in his maneuvers. The purpose of the present contract is to explore this context and to develop a computer program which offers an effective non-heuristic intelligently interactive simulation of one versus two aerial combat.

DISCUSSION

The Adaptive Maneuvering Logic begins with concern for the purpose of the decision makers in the game. The friendly pilot clearly recognizes six alternative outcomes in the two on one situation. He may kill both enemy aircraft and return home safely; kill either of the enemy aircraft and return safely; kill neither enemy aircraft and return safely; kill both enemy aircraft and not return safely; kill either of the enemy aircraft and not return safely; or kill neither and not return safely. These six alternative outcomes are weighted in desirability. Typically these might be 10, 9, 8, 2, 1, and 0, respectively. Obviously, the pilot on a kamikaze assignment would hold a different weighting of these outcomes.

But the maneuvers chosen by the pilot must reflect not only his own purpose but also that of the enemy. A presumption is made as to the nature of their view of what must be accomplished. In certain real situations their intent might be to deter further sorties in a particular area without triggering a conflict. If that be the case, then they do not wish to achieve a kill but merely force the friendly to return home safely. Under surge combat conditions wherein the enemy has many more aircraft than we do, the value of killing both enemy aircraft is much greater than simply killing either of them. In other words, the maneuvers chosen in the combat must reflect the priorities assigned to each alternative outcome, a complete expression of the purpose to be achieved by each of the decision makers involved. Indeed, without consideration of such purpose, any simulation is doubly dangerous . . . either equal weights of relative importance are tacitly assumed or it fails to reflect the essential nature and driving force of actual combat.

At this point, it is approriate to consider the geometric aspects of the situation, then focus on additional dimensions within the dynamics of the game, such as those concerned with energy/maneuverability.

Several approaches to the simulation of one-vs-two air combat were considered and abandoned for various reasons. The rationale behind the approach selected was strongly influenced by the following thoughts: (1) The best defense is a good offense. (2) If the friendly is on the offensive against a bandit and does not fly against that bandit as aggressively as possible, then that bandit will be the victor regardless of what the second bandit may or may not do. (3) It is highly desirable to live to fight another day. (This cannot, of course, be carried to the extreme or aerial combat cannot occur.)

The approach selected was to divide different possible situations into ten engagement classes and then determine which of the hostiles to engage. Also the weights selected for the purpose or criteria used to determine the optimal move for the next second can vary from class to class. A monitor subroutine was developed to determine the appropriate engagement class and the hostile to engage.

MONITOR SUBROUTINE

The purpose of the Monitor Subroutine is to determine the engagement class and the hostile to engage. The evaluation sequence is as follows:

If both hostile are forward of the friendly, then the engagement class will be from Classes 1 through 6, see Figure 1; otherwise the selection will be from Classes 7 through 10.

CLASS 1

The range to each hostile is greater than the maximum weapon range of the friendly. The maximum weapon range of the friendly against each hostile is determined from the deviation angle from each hostile. The equations are shown in Figure 2.

HOSTILE SELECTED

The hostile at which the friendly can fire first. The predicted time-to-fire (t_f) at each hostile is determined from:

$$t_f = \frac{A_o}{\dot{A}_m} + \frac{R - R_W}{\dot{R}} + .5 \text{ , sec}$$

where,

A_o = LOS angle from the friendly, see Figure 3.

$\dot{A}_m$ = maximum angular turn rate possible for the friendly.

R = range of the hostile from the friendly.

R_w = maximum range of friendly's weapon, as determined from Figure 2.

$\dot{R}$ = range rate for friendly pointed at the hostile. This is computed from:

$$
\begin{aligned}
\dot{R} \quad = \quad & X_H - X_F \quad \dot{X}_H - V_F \quad \frac{X_H - X_F}{R} \quad + \\
& Y_H - Y_F \quad \dot{Y}_H - V_F \quad \frac{Y_H - X_F}{R} \quad + \\
& Z_H - Z_P \quad \dot{Z}_H - V_F \quad \frac{Z_H - Z_F}{R} \qquad / \ R
\end{aligned}
$$

where,

X_F, Y_F, Z_F = XYZ position of the friendly measured along the initial or ground coordinate axes, ft.

X_H, Y_H, Z_H = as above for the hostile, ft.

$\dot{X}_H$, $\dot{Y}_H$, $\dot{Z}_H$ = velocity components of the hostile, along the initial or ground coordinate axes, ft/sec.

R = range between the hostile and friendly, ft.

V_F = magnitude of friendly velocity vector, ft/sec.

CLASS 2

Both hostiles are within the weapon range limits of the friendly. The weapon range limits are determined from Figure 2.

HOSTILE SELECTED

The one for which the LOS angle from the friendly is the smaller.

CLASS 3

The range to each hostile is less than the minimum weapon range of the friendly for that hostile.

HOSTILE SELECTED

The one for which the deviation angle from the hostile is the larger.

CLASS 4

One hostile is within the weapon range limits of the friendly, and the other is at a range greater than the maximum weapon range of the friendly.

HOSTILE SELECTED

The one for which the friendly's time-to-fire is the smaller. The time-to-fire (t_f) at the hostile within the weapon range limits is determined from:

$$t_f = \frac{A_o}{\dot{A}_m} + .5 \text{ , seconds}$$

where the terms are defined in Class 1. The time-to-fire at the hostile whose range is greater than the maximum weapon range is determined from the same equation given in Class 1.

CLASS 5

One hostile is within the weapon range limits of the friendly, and the other is at a range less than the minimum weapon range.

HOSTILE SELECTED

The one that is within the weapon range limits of the friendly.

CLASS 6

One hostile is at a range less than the minimum weapon range limit of the friendly and the other hostile is at a range greater than the maximum weapon range.

HOSTILE SELECTED

The one that has the minimum range.

CLASS 7 (See Figure 4)

One hostile:

1. has a LOS angle from the friendly that is greater than 120°, and

2A. the deviation angle from this hostile to the friendly is greater than 90°, or

2B. the range is greater than the maximum weapon range of the hostile (same as Figure 2 with roles reversed).

The other hostile has a LOS angle from the friendly that is less than 120°.

HOSTILE SELECTED

The one that has a LOS angle from the friendly that is less than 120°.

CLASS 8 (See Figure 5)

One hostile:

1. has a LOS angle from the friendly that is greater than 120°, and

2. the deviation angle from this hostile to the friendly is less than 90°, and

3. the range is less than the maximum weapon range of the hostile.

The other hostile has a LOS angle from the friendly that is less than 120°.

HOSTILE SELECTED

The one that has a LOS angle from the friendly that is greater than 120°.

CLASS 9 (See Figure 6)

Both hostiles are behind the friendly, and they are not in Classes 7 or 8.

HOSTILE SELECTED

Neither. Select a centroid point between the two.

CLASS 10 (See Figure 7)

One hostile is forward and the other is behind the friendly, and they are not in Classes 7 or 8.

HOSTILE SELECTED

The one forward.

CRITERIA

Twenty four different criteria items were used in determining the trial maneuver to be used. Actually, criteria 12 through 22 are essentially the same as 1 through 11 except relative to the second hostile. The criteria and evaluation for each follow:

Criterion 1 - Angle between friendly body x-axis and LOS vector to hostile 1. Value varies nonlinearly from 1 at zero angle to 0 at π angle; Formula for value v is given by:

$$v = (1 - (LOSFH/\pi)^2) / (1 + 2(LOSFH/\pi)^2)$$

where LOSFH is LOS angle from friendly to hostile.

Criterion 2 - Angle between hostile body x-axis and LOS vector to friendly. Value varies nonlinearly from 0 at zero angle to 1 at π angle except for head-on case. For non head-on case (both LOS angles greater than 30°) value v is given by

$$v = 1 - (1 - (LOSHF/\pi)^2) / (1 + 2(LOSHF/\pi)^2)$$

where LOSHF is LOS angle from hostile to friendly. For head-on case, value v is given by

$$v = 1 / (1 + (LOSHF \times 12.0)/\pi)^2$$

CRITERION 3 - Difference in altitude. Value varies nonlinearly from 1 at coaltitude to 0.5 at difference of 3,000 ft., to 0.2 at 6,000 ft. difference and then asymptotically to 0. Value v is given by:

$$V = 1 / (1 + (\Delta Z/3{,}000)^2)$$

where ΔZ is difference in altitude in feet.

Criterion 4 - Hostile range relative to center of weapon envelope of the friendly. Value varies nonlinearly from one at center to zero on boundary or outside envelope. If range is outside envelope, value v is zero, otherwise:

$$v = 1 - (RWF)^2$$

where,

$$RWF = |RMID - RFH| / (RMID - RMIN)$$

$$RMID = (RMAX + RMIN) / 2$$

RMAX = Maximum range of friendly weapon along LOS from hostile.

RMIN = Minimum range of friendly weapon along LOS from hostile.

RFH = Range between friendly and hostile.

Criterion 5 - Friendly range relative to hostile weapon envelope. Value varies nonlinearly from zero at center of hostile weapon envelope to one at boundaries or outside. Value v is one if friendly in outside hostile weapon envelope, otherwise:

$$v = (RWH)^2$$

where,

RWH	=	|RMIDH - RFH| / (RMIDH - RMINH)
RMIDH	=	(RMAXH + RMINH) / 2
RMAXH	=	Maximum range of hostile weapon along LOS from friendly.
RMIHN	=	Minimum range of hostile weapon along LOS from friendly.
RFH	=	Range between friendly and hostile.

<u>Criterion 6</u> - Range rate, $\dot{R}$, between hostile and friendly. Auxiliary function F is defined by:

$$F = \begin{cases} -1 & \text{if } \dot{R} > 2{,}000 \\ 1 - (2{,}000 + \dot{R}) / 2{,}000 & \text{if } -2{,}000 \leq \dot{R} \leq 2{,}000 \text{ ft/sec} \\ 1 & \text{if } \dot{R} < -2{,}000 \end{cases}$$

Then the value v is given by:

$$v = (1 + F \cos(\text{LOSFH})) / 2$$

If $\dot{R} > 0$ (an opening range rate), then F varies from zero to -1 as $\dot{R}$ varies from zero ft/sec to 2,000 ft/sec. If friendly is directly behind the hostile, v varies from 1/2 to 0 as range rates increases from 0 ft/sec to 2,000 ft/sec. If hostile is directly behind the friendly, v ranges from 1/2 to 1 as $\dot{R}$ increases from 0 ft/sec to 2,000 ft/sec. That is, when $\dot{R}$ is 0 value is 1/2 in the extreme cases of one being directly behind the other, but decreases when friendly is behind hostile as $\dot{R}$ increases since friendly cannot close on hostile. On the other hand, it increases when hostile is behind friendly as $\dot{R}$ increases since hostile cannot close on friendly.

If $\dot{R} < 0$ (a closing range rate) the F varies from zero to 1 as $\dot{R}$ decreases from 0 ft/sec to 2,000 ft/sec. This reverses the variation in v for the two different extreme cases. This agrees with the fact that when friendly is behind the hostile, a closing rate rate is favorable to the friendly but is unfavorable in the other case.

<u>Criterion 7</u> - Velocity. Except for the head-on case, for a positive value the friendly should have a speed advantage. The rule chosen was a value of 1 at a 10% speed advantage, decreasing to zero as speed advantage goes to zero and also decreasing slowly to zero as speed advantage increases beyond 10%.

For the head-on case (both LOS angles less than 30°) the desirable speed is that which allows the friendly to execute the quickest and tightest turn. This speed is called the corner velocity and is denoted as V_C.

For the head-on case, an auxiliary variable Δv is defined by:

$$\Delta v = (V_F - .9V_C) / .1V_C$$

where, V_F is velocity of friendly. Otherwise ΔV is defined by:

$$\Delta V = (V_F - V_H) / .1V_H$$

where V_H is velocity of hostile. The value v is defined by

$$v = \begin{cases} 0 & \text{if } \Delta V < 0 \\ \Delta V^{1/2} & \text{if } 0 \leq \Delta V \leq 1 \\ 2(1 - \Delta V) & \text{if } \Delta V > 1 \end{cases}$$

<u>Criterion 8</u> - Specific energy. The specific energy of an aircraft is defined as its potential energy plus its kinetic energy, divided by its weight: This is expressed as:

$$E_s = \frac{PE + KE}{W} = \frac{hW + (1/2)mV^2}{W} = h + v^2/2g, \text{ ft.}$$

where,

PE = Potential energy, ft-lbs

KE = Kinetic energy, ft-lbs

W = Weight of aircraft, lbs, (= mg)

h = Altitude of aircraft, ft

V = Velocity of aircraft, ft/sec

The difference between the specific energies of the friendly and a given hostile is then expressed as:

$$\Delta E_s = (E_{sF} - E_{sH}) = (h_F + V_F^2/2g) - (h_H + V_H^2/2g)$$

$$\Delta E_s = \Delta h - (v_F^2 - V_H^2) / 2g$$

where,

Δh = difference in altitude between friendly and hostile, ft.

V_F, V_H = velocity of friendly and hostile respectively, ft/sec.

If the friendly has a 20% speed advantage and is at the same altitude as the hostile:

$$\Delta E_s = ((1.2V_H)^2 - V_H^2) / 2g = 0.007 V_H^2$$

If the hostile is at 500 knots (844 ft/sec),

$$\Delta E_s = 4{,}986 \text{ ft.}$$

In other words, if the friendly has a 20% speed advantage over the hostile and is 4,986 feet below the hostile, the difference in specific energy is zero. If the friendly is 4,986 feet above the hostile, with a 20% speed advantage, the specific energy is twice that at coaltitude.

The value v is obtained as follows:

Let $ER = .007 V_H^2$

$EXP = (E_{sF} - E_{sH} - ER) / ER$

then the value v is given by

$$v = 2^{-EXP} \text{ if } EXP > 0 \text{ and } 2^{EXP} \text{ if } EXP \leq 0$$

Criterion 9 - Difference in time between when the friendly can fire and when the hostile can fire. It is desirable for the friendly to be able to fire before the hostile. If the friendly can fire five seconds or more before the hostile can, the value function is one. This value decreases slowly as the time difference decreases to three seconds and then approaches zero more rapidly as the time difference goes to zero. It remains at zero as long as the hostile can fire first.

Value v is computed as follows:

If range rate is opening (positive or zero) and hostile is outside the weapon envelope of the friendly, v = 0. If range rate is opening and friendly is outside the weapon envelope of the hostile, v = 1; otherwise, the time to fire is computed for both. If opponent is within plane's weapon range, time to fire equals LOS/u where u is the maximum turn rate. If outside weapon range, time to fire is LOS/u plus distance outside weapon envelope/|range rate|. Let TH be time for hostile to fire and TF time for friendly and let DT = TH - TF then

$$v = \begin{cases} 0 & \text{if } DT < 0 \\ (DT/5)^{1/2} & \text{if } 0 \leq DT \leq 5 \\ 1 & \text{if } DT > 5 \end{cases}$$

<u>Criterion 10</u> - Can friendly see hostile. The friendly can see the hostile if the hostile is above a plane through the body y-axis of the friendly and 30 degrees down from friendly's body x-axis. If hostile can be seen, value is 1 otherwise zero.

If Z' is the z-axis coordinate of the hostile in the coordinate system of 30° plane through the body y-axis, then if $Z' < 0$ (z-axis is positive downward) hostile is visible to friendly and value is 1. If $Z' \geq 0$, value is 0 as hostile is not visible.

<u>Criterion 11</u> - Can hostile not see friendly. This is same problem as criterion 10 except with respect to hostile body axis and 30° plane through body y-axis. Further if friendly can be seen, value is zero, otherwise it is one.

Criterion 12 through 22 are the same as Criterion 1 through 11 except with respect to the second hostile.

<u>Criterion 23</u> - First one that can fire. The times to fire for each aircraft are available from Criterion 9 and 20. The minimum of the two times for the friendly to fire is obtained as well as the hostile with the minimum times. The value is obtained as in Criteria 9 or 20 using the minimum times.

<u>Criterion 24</u> - Can friendly see both hostiles. The value functions from Criteria 11 and 22 are used. If both are 1, the value for 24 is also 1 otherwise it is zero.

MANEUVERS AND INPUTS

Trial Maneuvers and Weights

At each decision point, normally every second, the program sets up trial maneuvers for the friendly*, scores them and choses the one with the highest score as the maneuver to perform at that time. Maneuver 1 through NTRYT1 (a counter) are referenced to hostile 1 in choice of maneuvering planes while those from NTRYT2 through NTRYT (counter of all maneuvers) are referenced to hostile 2 in choice of maneuvering planes.

In computing a score for each trial maneuver, a weighted sum of the values of the 24 criteria for that maneuver is computed. The weights are in a weight table of three parameters, criterion number, class number and hostile number. That is, each class-hostile pair has its own set of weights for the criteria. In one operation mode, the class-hostile pair is determined by the Monitor Subroutine. (The mode is determined by an input variable, KOPT. KOPT = 1 for this mode and 2 for the other). In the second mode, the class is still determined by the Monitor Subroutine but hostile 1 is chosen for trial maneuvers 1 through NTRYT1 and hostile 2 for the remaining trial maneuvers.

Hostile Flight Paths

After considering several alternates for debugging purposes it was decided to have the hostiles fly in figure eight flight paths. Since using various initial start positions for the single aircraft against the developed figure eight flight path data could be utilized to check out the "reasonableness" of maneuvers executed by the DSI developed program. Further, the figure eight flight path

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*For a complete description of the trial maneuver see Reference I.

permitted an offset one behind the other formation so that the first opposing aircraft was supported by the second. Also, both left and right turns could be made through use of the same data, that is, by using differing initial start positions for the single fighter and the two hostiles both left and right turns as well as straight flight either before or after the turn were available. (Figure 8) Both aircraft fly at a constant speed and altitude (input data). Hostile 1 starts at point A and flies a 3g clockwise turn of 232.48° to point B. The second leg is a straight line path of the same length as the circular leg AB. At point C it flies a 3g counterclockwise turn of 232.42° to point D and then a straight line path to starting point A. Hostile 2 starts its flight TIMEH2 (an input parameter) seconds ahead of point A on the path. Actually all points of hostile 2 path are offset 1,000 ft in the positive x-axis direction so that the paths of the two hostiles do not overlap in the graphic printout.

Attempts to get some real flight data from ACMI to run the AML simulation against were not successful, so all runs were made with the hostiles flying segments of the figure eight paths.

Input Data Requirements

The input data required to run the off-line program can be classified into three groups. The first group describes the atmospheric model used in the simulation. A second group of data defines the friendly aircraft engaged in the simulation. These first two sets of data remain unchanged from one engagement to the next during a computer job. For each engagement simulated, a set of cards of the third group is needed. These data define the geometrical initial conditions, the weight factors for the calculation of cell values and such run control parameters as duration of engagement, and requests for printing and plotting. Several engagements may be simulated in one job, each engagement requires an additional set of input variables of this third group.

Input data cards are grouped into eight individual groups. The data cards for each group must be preceded with a card which contains a code word. This code word consists of four characters punched in columns 1 through 4.

Atmospheric Model Definition - Code Word: ATMO

(a) The speed of sound c_s (FORTRAN name CSO) in ft/sec is tabulated as a function of altitude at 500 feet intervals from sea level to 60,000 feet.

121 values   13 cards   FORMAT (10F8.7)

(b) Air Density ρ (FORTRAN name RHO) in lbs sec^2/ft is tabulated as a function of altitude at 500 feet intervals from sea level to 60,000 feet.

121 values   13 cards   FORMAT (10F8.7)

Aircraft Identification and Wing Area - Code Word: FRND.

The aircraft identification card is followed by one card containing the wing reference area (FORTRAN name SURF) in $feet^2$.

1 value   1 card   FORMAT (10F8.7)

Load Factor Information - Code Word: LDFT

(a) The maximum permissible load factor (FORTRAN name F4VG) in g's is tabulated as a function of altitude and Mach number. One card each for the following altitudes (sea level, 15,000, 30,000, 45,000 and 55,000 feet) contains maximum load factors for the following 12 Mach numbers (0.2, 0.5, 0.8, 0.9, 1.0, 1.1, 1.2, 1.5, 1.8, 2.0, 2.2 and 2.4).

60 values   5 cards   FORMAT (15F5.2)

(b) The sustained load factor (FORTRAN name F4SG) in g's is tabulated as a function of altitude and Mach number for the same altitudes and Mach numbers as the maximum load factor.

60 values   5 cards   FORMAT (15F5.2)

Engine Performance Data - Code Word: ENGN

All thrust data is given for one engine, the program multiplies thrust by two, assuming two engine aircraft.

(a) Idle thrust (FORTRAN name TIDLE) in lbs. is tabulated as a function of altitude and Mach number. There are two cards for each of the following altitudes (sea level, 10,000, 20,000, 30,000, 40,000, 50,000 and 60,000 feet) containing thrust values for the 14 Mach numbers (0.2, 0.4, 0.6, 0.8, 0.9, 1.0, 1.1, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2 and 2.4).

98 values   14 cards   FORMAT (7F10.0)

(b) Military thrust (FORTRAN name TMIL) in lbs. is tabulated as a function of altitude and Mach number. The same seven altitudes and 14 Mach numbers as for the idle thrust table are used.

98 values   14 cards   FORMAT (7F10.0)

(c) Afterburner thrust (FORTRAN name TAB) in lbs. is tabulated as a function of altitude and Mach number. The same seven altitudes and 14 Mach numbers as for the idle thrust table are used.

98 values   14 cards   FORMAT (7F10.0)

Aerodynamic Data - Code Word: ARDT

(a) Angle of attack α with slats/flaps fully retracted (FORTRAN name F4ALP) in degrees is tabulated as a function of lift coefficient (C_L) and Mach number. Each card contains the angle of attack for one value of lift coefficient and 10 values of Mach numbers. The lift coefficient ranges from 0 to 2.0 in equal intervals of 0.1. The following 10 points of Mach numbers are used (0.2, 0.5, 0.8, 0.9, 1.0, 1.1, 1.2, 1.5, 1.8 and 2.0).

210 values   21 cards   FORMAT (10F8.7)

(b) Angle of attack α with slats/flaps fully extended (FORTRAN name F5ALP) in degrees is tabulated as a function of lift coefficient and Mach number for the same values of coefficient of lift and Mach numbers as under (a) above.

210 values 21 cards FORMAT (10F8.7)

(c) Coefficient of drag C_{D_U} with slats/flaps fully retracted (FORTRAN name F4CDR) is tabulated as a function of lift coefficient and Mach number for the same values of coefficient of lift and Mach numbers as under (a) above.

210 values 21 cards FORMAT (10F8.7)

(d) Coefficient of drag C_{D_D} with slats/flaps fully extended (FORTRAN name F5CDR) is tabulated as a function of lift coefficient and Mach number in the same arrangement as given under (a) above.

210 values 21 cards FORMAT (10F8.7)

Limits - Code Word: LMTS

(a) Maximum lift coefficient $C_{L_{max}}$ (FORTRAN name CLMAX) is tabulated as a function of Mach number for 14 Mach numbers (0.2, 0.4, 0.6, 0.8, 0.9, 1.0, 1.1, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4).

14 values 1 card FORMAT (15F5.2)

(b) Minimum Mach number (FORTRAN name F4MMI) is tabulated as a function of altitude for 13 values (sea level to 60,000 feet in increments of 5,000 feet)

13 values 1 card FORMAT (15F5.2)

(c) Maximum Mach number (FORTRAN name F4MMA) is tabulated as a function of altitude for the same altitudes as in (b) above.

13 values 1 card FORMAT (15F5.2)

(d) Dive recovery angle (FORTRAN name RECANG) in degrees is tabulated as a function of altitude and Mach number. There are ten cards for altitude intervals of 5,000 feet from sea level to 45,000 feet. (Dive recovery has no limit above 45,000 feet.) Each card contains values for 12 Mach numbers (0.2, 0.5, 0.8, 0.9, 1.0, 1.1, 1.2, 1.5, 1.8, 2.0, 2.2, 2.4).

120 values	10 cards	FORMAT (15F5.2)

Speed Brake Drag Coefficient - Code Word: SPBR

(a) The drag coefficient increment (FORTRAN name SBCDR) for fully deflected speed brakes is tabulated as a function of the 14 Mach numbers (0.2, 0.4, 0.6, 0.8, 0.9, 1.0, 1.1, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2 and 2.4).

14 values	1 card	FORMAT (15F5.2)

The final card of the input defining the aircraft is a control card for printing of all the data read so far. If this card contains the code word PRNT in the first four columns, atmospheric data and aircraft data will be printed. If the first four columns contain anything else than the code word PRNT, printing of these tables will be suppressed.

INPUT DATA FOR ENGAGEMENTS

Card 1 is for title which can be up to 80 characters.

Card 2 contains the weight and weapons of the friendly. For F-4, weight is 42,000 lbs. Code for gun is 20, for missiles not equal to 20.

Card 3 contains code word KOPT. If KOPT = 1, weights are taken from the weight table with class and hostile as determined by the monitor. If KOPT = 2, class is as determined by the monitor but for trail maneuvers 1 through NTRYT1 hostile 1 is used; for the other trial maneuvers hostile 2 is usual.

Card 4 contains the friendly start position (X_F, Y_F, H_F), velocity V_F and direction (Ψ_F, Θ_F, Φ_F).

Card 5 contains the friendly's tactical decision parameters (FSTRGF, GLEVLE, TPOSF, DTPRE, TIMEPF, FNTILF). FSTRGF = 1 indicates straight flight with belly down, = -1 for straight flight with belly up and = 0 for turn into a maneuver plane. GLEVLE is the load factor ratio for initial turn, TPOSF is the throttle position, DTPRF is the time between decisions, TIMEPF is the prediction time increment and ENTILF is the tilt angle increment for maneuver planes.

Card 6 contains the hostile 1 start position (X_H, Y_H, H_H), velocity V_H and direction (Ψ_H, Θ_H, Φ_H).

Card 7 contains the time, TIMEH2, that hostile 2 is ahead of hostile 1 as well as the weaponry for both hostiles, WEAPONH(1) and WEAPONH(2).

Card 8 contains the program control data, (TBEGN, TEND, DT, FKPR, FKAPR, FKTAP). TBEGN is start time of simulation, TEND is stop time of simulation, DT is integration time step, FKPR is number of time steps between printouts, FKAPR is print control word and FKTAP is the tape interval (negative for no tape). The print-control-value (PCV) in FKAPR and type of printout controlled are: PCV = 1, print weight-table, = 2 print actual tactical situation, = 4 print actual state space values, = 8 print table of trial maneuvers with g's and normal accelerations, = 16 print table of trial maneuvers with total value of maneuver, = 32 print table of individual values for trial maneuvers, = 64 print relative geometry, = 128 print aircraft parameters, and, = 256 print maneuver plane rotation angle. Multiple printouts are achieved by summing the codes.

There are then 3 sets of 24 cards containing the weights for the criteria for hostile 1, hostile 2 and the case where the midpoint between the hostiles used to determine maneuvering planes. Each card contains nine values for the weights for the different classes. (Class 9 and 10 always have the same weights. Weights for Class 10 were not included. The program adjusts for this).

Appendix A contains a printout of a set of input data.

SAMPLE ENGAGEMENTS

In developing the one-versus-two AML offline program, many engagements with various initial conditions, with two different types of friendly aircraft (F-4 and F-14) and for various durations were simulated.

During execution of the program, detailed printout of the status of the combatants aircraft, of the relative geometry, of the tactical situation, of the predicted outcomes of the different trial maneuvers and of the worth of the trial maneuvers can be generated. (See description of print-option selector KAPR in section "Input Data for Engagements"). Figure 9 shows an example of the printout for the aircraft status. Figure 10 is an example of the printout of the tactical situation. In addition, the program has an option to record selected variables at specified intervals of time for subsequent processing by plotting routines.

Two auxiliary plotting programs were written: one to plot a ground trace (projection of the 3 trajectories onto the x_e, y_e plane), the other to plot time histories of the friendly's value-function.

Ground trace plots are shown for four engagements. For the first two of these engagements, the corresponding time histories of the weighted value functions are also given.

The first two examples have exactly the same initial conditions (as shown in Figures 9 and 10); they differ only in the mode (value of KOPT) which is equivalent to changing the assigned weights to the 24 criteria.

In all four examples, the hostiles flight paths were segments of the canned figure 8 trajectory, as described in the section "Hostile Flight Paths." Hostile 1 flies a level turn with a constant load factor of three g's at a constant velocity of about 420 knots at an altitude of 20,000 feet. Hostile 2 flies a constant level turn (with the same parameters as hostile 1) for 14 seconds and then continues with straight and level flight. Engagement 1 (the conservative pilot) was simulated for a duration of 30 seconds, ground traces of the trajectories are illustrated in Figure 11. Time is marked by dots in one second intervals, and symbols identifying the three trajectories are plotted every five seconds. When selecting weights for the valuated state space, the "conservative" pilot determines whether one of the opponents might become a serious threat in the near future. If this is the case, he will select a set of weights such that more importance is given to the threatening aircraft. This fact is nicely reflected in Figure 12, which shows the time history of the weighted values for friendly's valuated state space, broken down to values with respect to hostile 1 and hostile 2 separately. After about 10 seconds, the AML program succeeds in keeping the values with respect to the two hostiles about the same.

This second example starts with the same initial conditions as the engagement in example 1. The flight paths of the two hostiles are also the same as in the first example. The only difference between example 1 and example 2 is the weight selection in the decision process of the friendly. In example 2, he is less concerned about the hostiles becoming a threat to him and more concerned with achieving a kill against one of the hostiles. His weights, therefore, are more evenly distributed between questions concerning hostile 1 and those concerning hostile 2. By comparing Figure 12 and 14, this is demonstrated very clearly, after 30 seconds, the aggressive friendly is in a much better position against hostile 2 than the conservative friendly pilot. Throughout the experimental runs it was observed that the single aircraft flew more conservatively for those runs using the mode wherein the monitor selected that aircraft to which the single aircraft was to direct its attention (weights for the other aircraft were set to zero). On the other hand, the single aircraft appeared to fly more aggresively for those runs using the mode wherein the monitor did not select that aircraft to which the single aircraft was to direct its attention; that is, the trial maneuver selected was based upon the 12 criteria for both hostile aircraft. This led to the use of the terms aggressive and conservative pilot, simply meaning that the aggressive pilot would take greater risk to achieve an advantageous position than would the conservative pilot. A comparison of the two trajectories (Figure 11 and Figure 13) reveals that during the first ten seconds, the engagements are very similar. Between ten and twenty seconds, the aggressive pilot bears more to the west. The significant difference in maneuvering occurs after 20 seconds. The conservative pilot tries to prevent hostile 1 from "getting behind his tail," for hostile 2 at this point is of little interest. The conservative pilot, at time 22 seconds, initiates a right turn, thus maintaining a neutral situation between him and both of his opponents, at time 30 seconds, he has the same weighted value against both opponents.

In contrast, the aggressive pilot, at time 23 seconds, initiates a hard left turn, leaving him vulnerable against hostile 1 for four seconds, starting at time 21 seconds. At time 30 seconds, he has a decided advantage over the conservative pilot, an almost neutral situation against hostile 1, strongly offensive situation against hostile 2.

Several conclusions can be drawn from these first two examples. Most important, it shows the flexibility and inherent power of the Adaptive Maneuvering Logic: State a goal, adjust the weights accordingly and the aircraft will fly along a flight path along which, locally, the weighted state space value is maximized. It also shows the shortcoming and the danger of developing air-to-air combat techniques in a noninteractive environment. While the argument that in the computer program the friendly does not really know the opponent's flight paths ahead of the present time is true, it is nevertheless disturbing to analyze such engagements because it is often obvious that if a certain situation arises, an obvious reaction would take place; for example, in Figure 13, hostile 1 at 23 seconds clearly would have performed a max-g right turn.

The weights used in these first two examples were extreme in that one case paid maximum attention to the more threatening aircraft, the other one paid equal attention to both. It would be possible to adjust the weights between these two extremes continuously.

The last two examples illustrate the effect of different aircraft capabilities. Initial conditions were similar to those of the two first engagements except for a smaller initial range (14,000 feet horizontal separation between hostile 1 and friendly, 5,000 feet vertical separation). Figure 15 shows the ground trace of engagement 3, where the friendly aircraft was simulated to be an F-4, whereas in Figure 16 the friendly aircraft was an F-14. The tactics employed by the AML driving the two different aircraft were essentially the same; however, the F-14, due to its better turning capability and higher thrust to weight ratio, was able to perform a tight, climbing turn between 15 seconds and 30 seconds, which resulted in a significant positional advantage versus the F-4 at the end of the engagement.

SUMMARY

This report describes a computer program for the off-line simulation of air-to-air combat wherein a friendly aircraft engages two hostile aircraft. The method is based on the Adaptive Maneuvering Logic which is described elsewhere.

The approach selected was influenced by these concepts. (1) The best defense is a good offense. (2) If the friendly is on the offensive against a hostile and does not fly as aggressively as possible, the hostile may very well be the victor regardless of what the second hostile does. In the approach the different possible engagement configuration were divided into ten classes and within each class criteria was set up to determine which hostile to engage. A Monitor subroutine was developed to determine the appropriate engagement class and hostile to engage.

Twenty-four criteria were developed for scoring the trial maneuvers so as to choose the most optimal one, the one with the highest score. (Rules for computing the value of each criterion relative to the situation were developed). Each class-hostile pair had a set of weights for the criteria with the score being the sum of the products of the weight and the corresponding criteria value.

The hostile flight paths were fixed scenarios. Each hostile flew a figure 8 with constant speed and altitude and 3g turns. One hostile's path was TIMEH2 (input value) seconds ahead of the other and offset so as not to overlap.

In developing the one-versus-two offline program, many engagements with various initial conditions, with two different types of friendly aircraft (F-4 and F-14) and for various durations were simulated. Ground trace plots for four of the engagements are scheduled in the report.

In general the maneuvers by the friendly appear to be reasonable ones, although it is difficult to analyze the engagements since the hostiles are non-interactive. For example, the aggressive pilot in engagement two had a decided advantage over the conservative pilot of engagement 1 at time 30 seconds. On the other hand, at 23 seconds he was vulnerable to an offensive move by hostile 1 in an interactive environment. The last two examples illustrate the result of different aircraft capabilities. The higher performance F-14 had a definite positional advantage over the F-4 at the end of the engagement.

SYMBOLS

A_0	-	LOS angle from friendly to hostile
$\dot{A}_m$	-	Maximum angular turn rate
DT	-	Integration time step
DTPRF	-	Time between decisions
E_s	-	Specific energy
E_{sF}	-	Specific energy of friendly
E_{sH}	-	Specific energy of hostile
ENTILF	-	Tilt angle increment for maneuver planes
FKAPR	-	Point control word
FKPR	-	Number of time steps between printouts
FKTAP	-	Tape interval (negative for no tape)
FSTRGF	-	Decision parameter, 1 for straight flight belly down -1 for straight flight belly up, 0 for turn into a maneuver plane
GLEVLE	-	Load factor ratio for initial turn
h	-	Altitude of aircraft
h_F	-	Altitude of friendly aircraft
h_H	-	Altitude of hostile aircraft
KE	-	Kinetic energy
KOPT	-	Input variable for scoring mode
LOSFH	-	LOS angle from friendly to hostile
LOSHF	-	LOS angle from hostile to friendly
NTRYT	-	Total number of trial maneuvers
NTRYT1	-	Number of total maneuvers referenced to hostile 1
PE	-	Potential energy

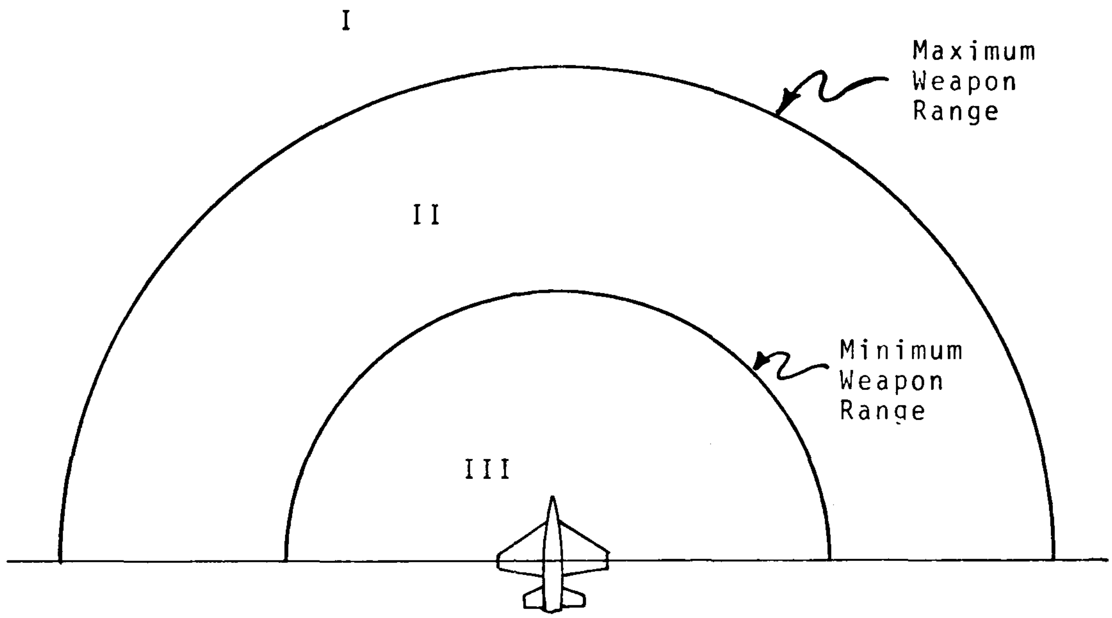
R	-	Range from friendly to hostile
$\dot{R}$	-	Range rate from friendly to hostile
RFH	-	Range from friendly to hostile
RMAX	-	Maximum range of friendly weapon along LOS from hostile
RMAXH	-	Maximum range of hostile weapon along LOS from friendly
RMIN	-	Minimum range of friendly weapon along LOS from hostile
RMINH	-	Minimum range of hostile weapon along LOS from friendly
t_f	-	Time to fire
TBEGN	-	Start time for simulation
TEND	-	End time for simulation
TIMEH2	-	Lead time of hostile 2 on figure 8 path
TPOSF	-	Throttle position
V_c	-	Corner velocity, i.e., velocity which allows tightest turn
V_F	-	Magnitude of friendly velocity
V_H	-	Magnitude of hostile velocity
W	-	Weight of aircraft
X_F, Y_F, Z_F	-	XYZ coordinates of friendly in ground coordinate axes
X_H, Y_H, Z_H	-	XYZ coordinates of hostile in ground coordinate axes
$\dot{X}_H$, $\dot{Y}_H$, $\dot{Z}_H$	-	XYZ velocity components of hostile in ground coordinate axis
Δh	-	$h_F - h_H$
ΔE_s	-	$E_{\Delta F} - E_{\Delta H}$
ΔZ	-	$h_F - h_H$
Ψ, Θ, Φ	-	Euler angles for aircraft

REFERENCES

1. Burgin, George H., Fogel, Lawrence J., and Phelps, J. Price, An Adaptive Maneuvering Logic Computer Program for the Simulation of One-on-One Air-to-Air Combat, Volume I: General Description, NASA Contractor Report NASA CR-2582, National Aeronautics and Space Administration, Washington, DC, September 1975.

2. Burgin, George H., and Owens, A. J., An Adaptive Maneuvering Logic Computer Program for the Simulation of One-on-One Air-to-Air Combat, Volume II: Program Description, NASA Contractor Report NASA CR-2583, National Aeronautics and Space Administation, Washington, DC, September 1975.

FIGURES



Class 1 - Both hostiles in area I

Class 2 - Both hostiles in area II

Class 3 - Both hostiles in area III

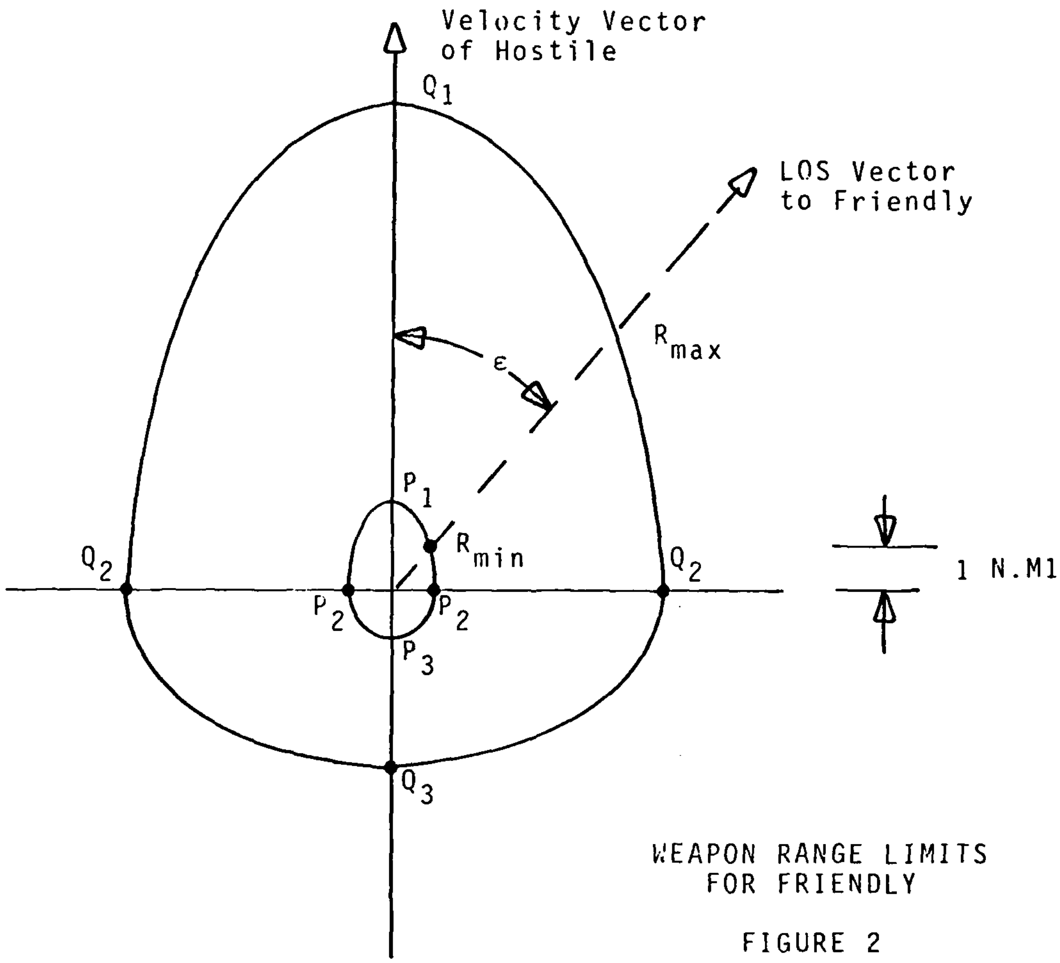
Class 4 - One hostile in area I, other in area II

Class 5 - One hostile in area II, other in area III

Class 6 - One hostile in area I, other in area III

CLASSES 1 TO 6

FIGURE 1



WEAPON RANGE LIMITS
FOR FRIENDLY

FIGURE 2

For missiles = (shown above)

Q_1 = 10. N.M	P_1 = 2. N.M
Q_2 = 5.	P_2 = 1.
Q_3 = 3.	P_3 = 5.

For guns = (not shown)

$Q_1 = Q_2 = Q_3 = .5$ N.M $\quad P_1 = P_2 = P_3 = 0$

The weapon range limits (R_{max} , R_{min}) are computed from:

If $\varepsilon \leq 90°$:

$$R_{max} = Q_1 - (Q_1 - Q_2) \sin \varepsilon \quad , \text{N.M}$$
$$R_{min} = P_1 - (P_1 - P_2) \sin \varepsilon$$

If $\varepsilon > 90°$:

$$R_{max} = Q_2 + (Q_2 - Q_3) \cos \varepsilon$$
$$R_{min} = P_2 + (P_2 - P_3) \cos \varepsilon$$

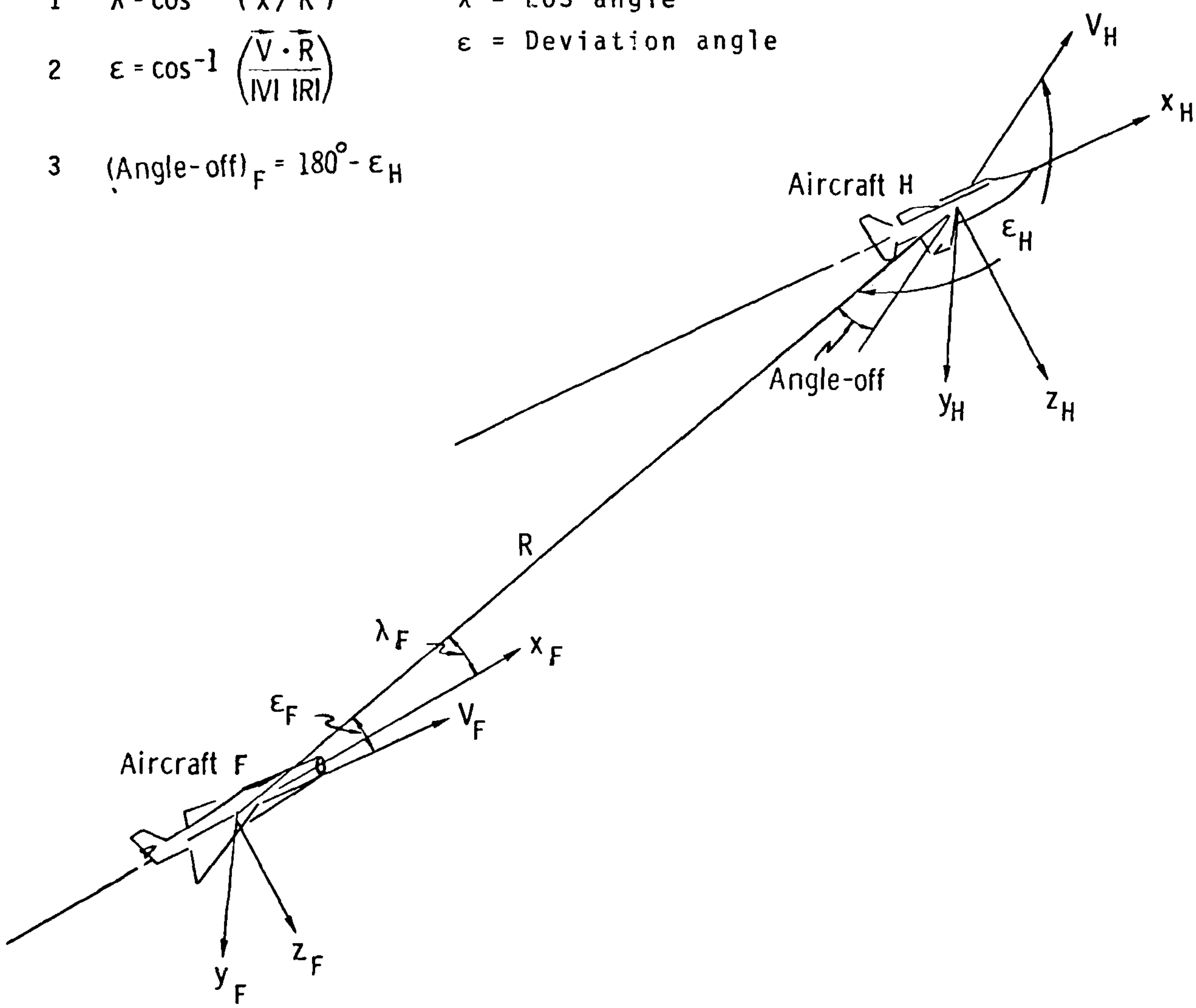
1 $\lambda = \cos^{-1}(x/R)$

2 $\varepsilon = \cos^{-1}\left(\dfrac{\vec{V} \cdot \vec{R}}{|V|\,|R|}\right)$

3 $(\text{Angle-off})_F = 180^\circ - \varepsilon_H$

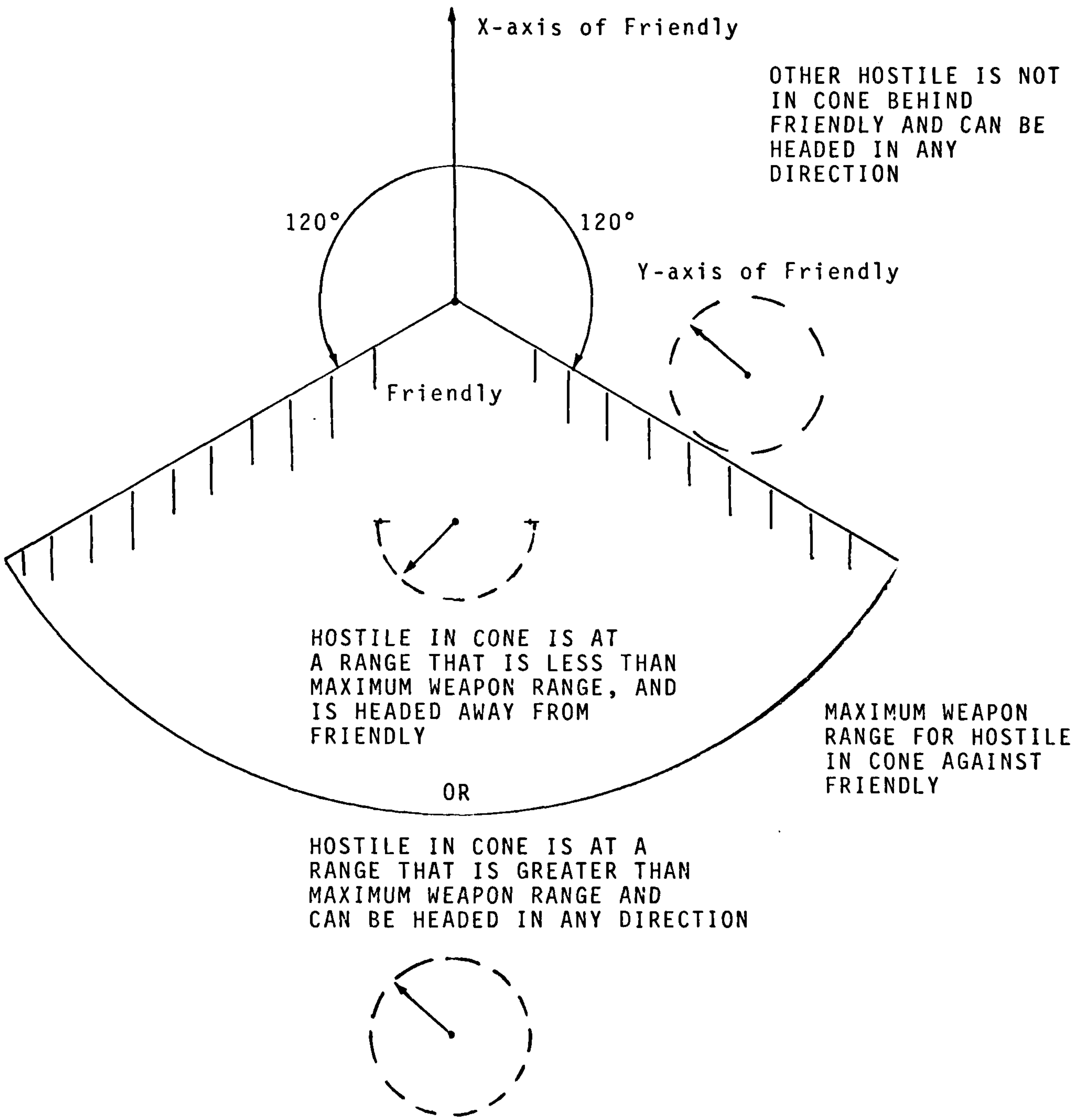
λ = LOS angle

ε = Deviation angle



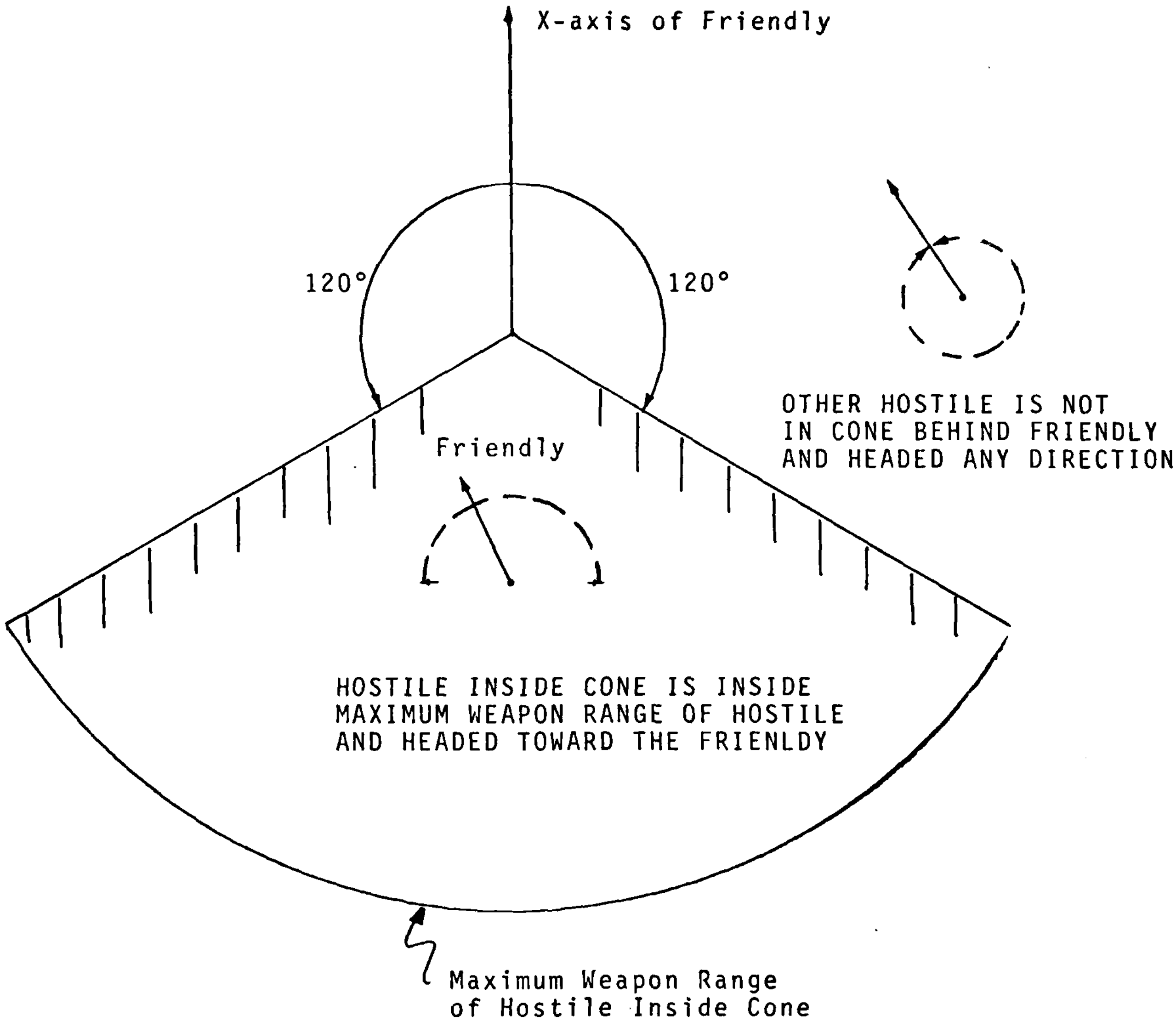
ANGULAR RELATIONS

FIGURE 3



One hostile is in a 60° cone behind the friendly and cannot fire its weapon and the other hostile is not in the cone. (The hostile outside the cone is selected for engagement.)

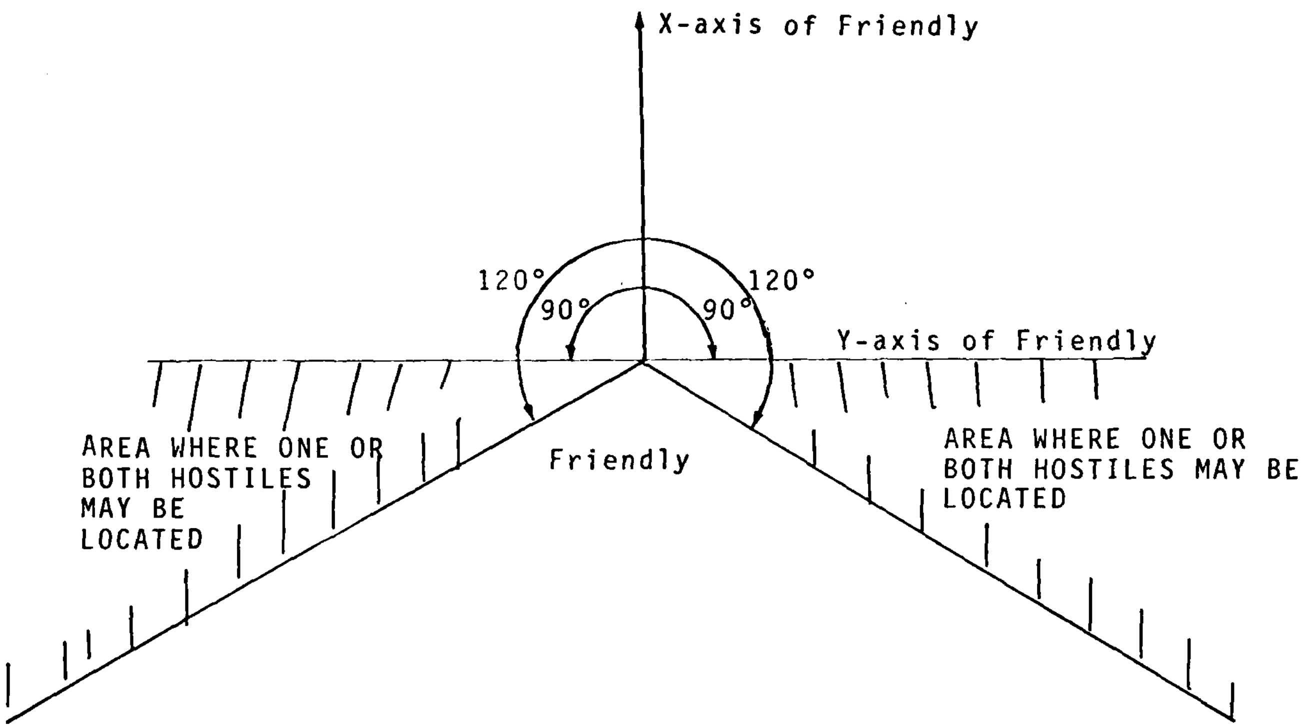
FIGURE 4: CLASS 7



One hostile is in a 60° cone behind the friendly and can fire its weapon at the friendly, and the other hostile is outside the cone. (The hostile inside the cone is selected for engagement.)

CLASS 8

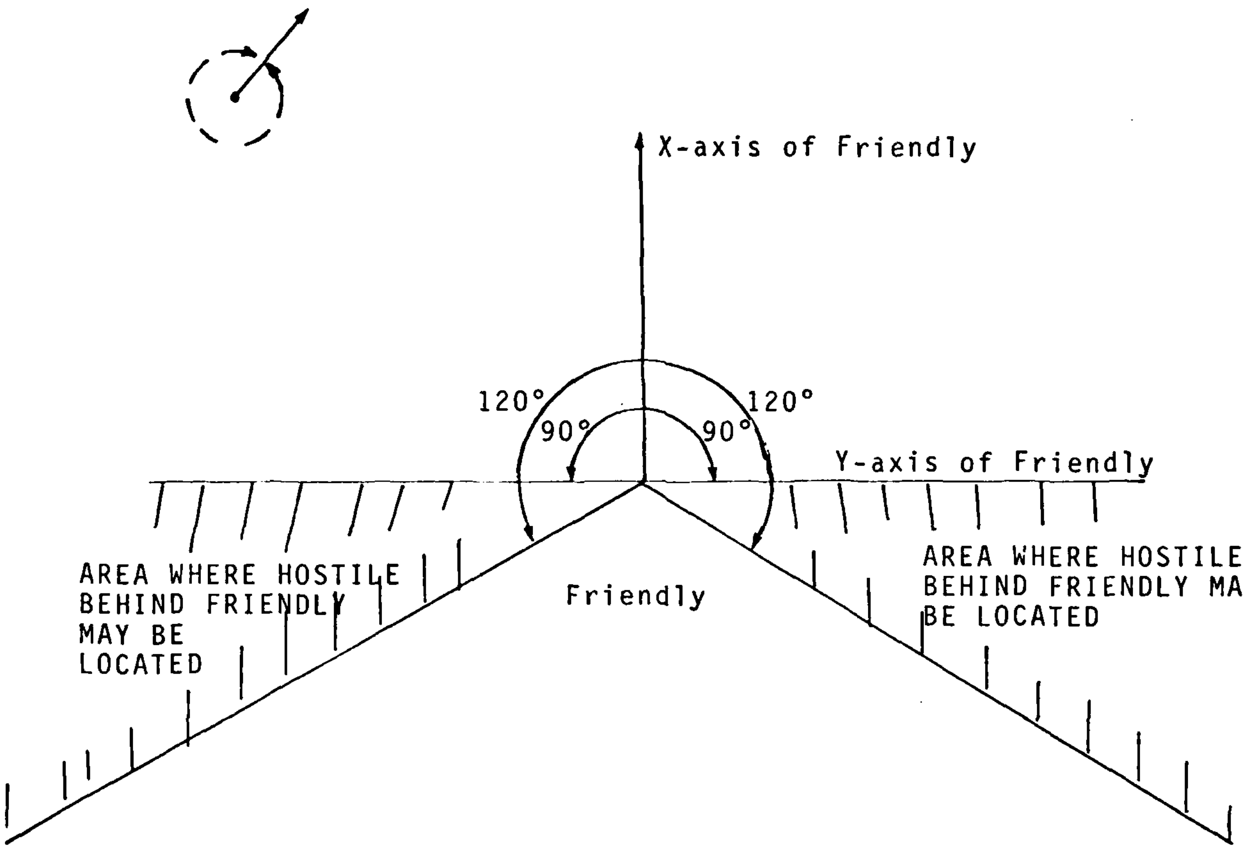
FIGURE 5



Both hostiles are between 90° AND 120° of the friendly X-axis and can be headed in any direction. (A point between the hostiles is selected for engagement.)

CLASS 9

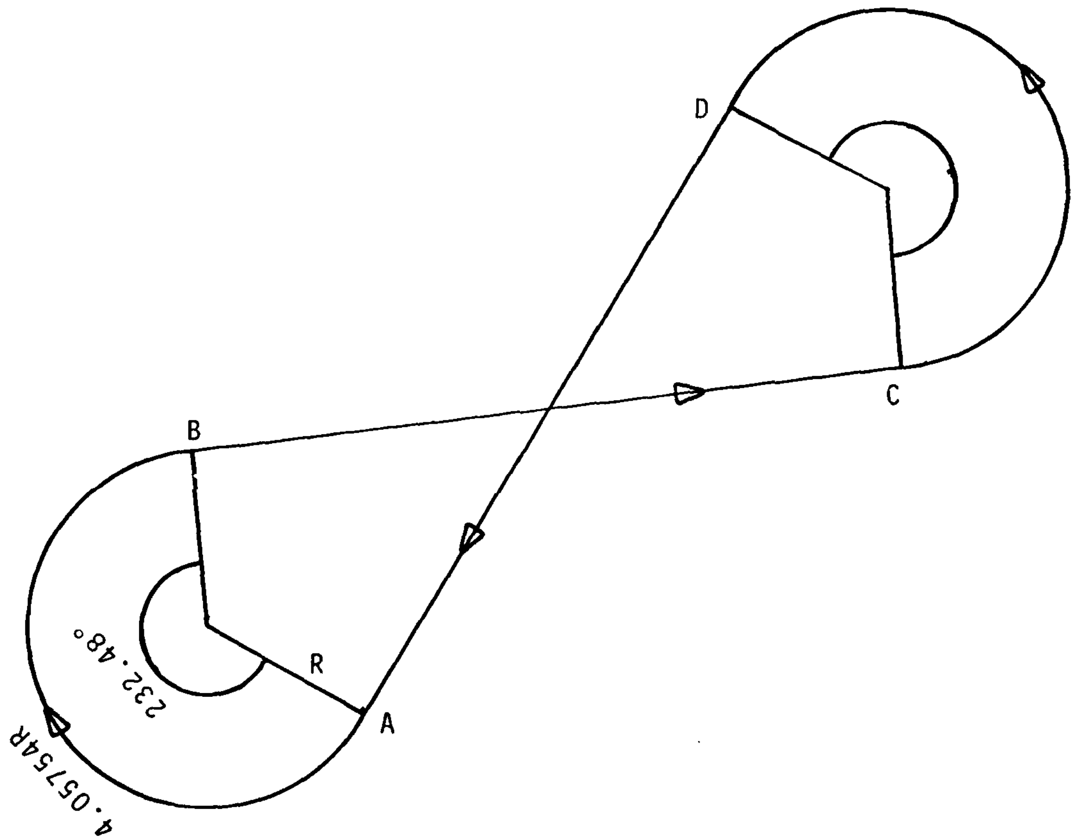
FIGURE 6



One hostile is forward of friendly and the other is between 90° and 120° behind the friendly. (The hostile forward of the friendly is selected for engagement.)

CLASS 10

FIGURE 7



HOSTILE FLIGHT PATH

FIGURE 8

FRIENDLY AND HOSTILE AIRCRAFT PARAMETERS

Time = 0.00 seconds

	FRND	HOST1	HOST2	UNITS
Mach No.	.76	.68	.68	-
True Air Speed	800.0	707.1	707.1	ft/sec
True Air Speed	474.0	419.0	419.0	knots
Ind. Air Speed	376.1	-	-	knots
Ang. of Attack	2.8	0.0	0.0	deg
Load Factor	1.0	-	-	g's
THETA (Pitch)	2.8	0.0	0.0	deg
PHI (Roll)	0.0	0.0	0.0	deg
PSI (Yaw)	45.0	45.0	162.4	deg
X Position	-15000.	7000.	4904.	ft
Y Position	7000.	7000.	15594.	ft
Altitude	15000.	20000.	20000.	ft
X rate	566.	500.	-674.	ft/sec
Y Rate	566.	500.	214.	ft/sec
Alt. Rate (+ = Up)	0.	0.	0.	ft/sec
P (Body Roll Rate)	.0	-	-	deg/sec
Q (Body Pitch Rate)	44.9	-	-	deg/sec
R (Body Yaw RAte)	-.0	-	-	deg/sec
Throttle Pos.	2.	-	-	-
Thrust	25095.	-	-	lbs
Drag	5985.	-	-	lbs
Spec. Energy/100	24.9	27.8	27.8	ft
Spec. EnergyRate	364.0	-	-	ft/sec
Max. Load Factor	5.7	-	-	g's

INITIAL CONDITIONS FOR THE
FIRST TWO SAMPLE ENGAGEMENTS

FIGURE 9

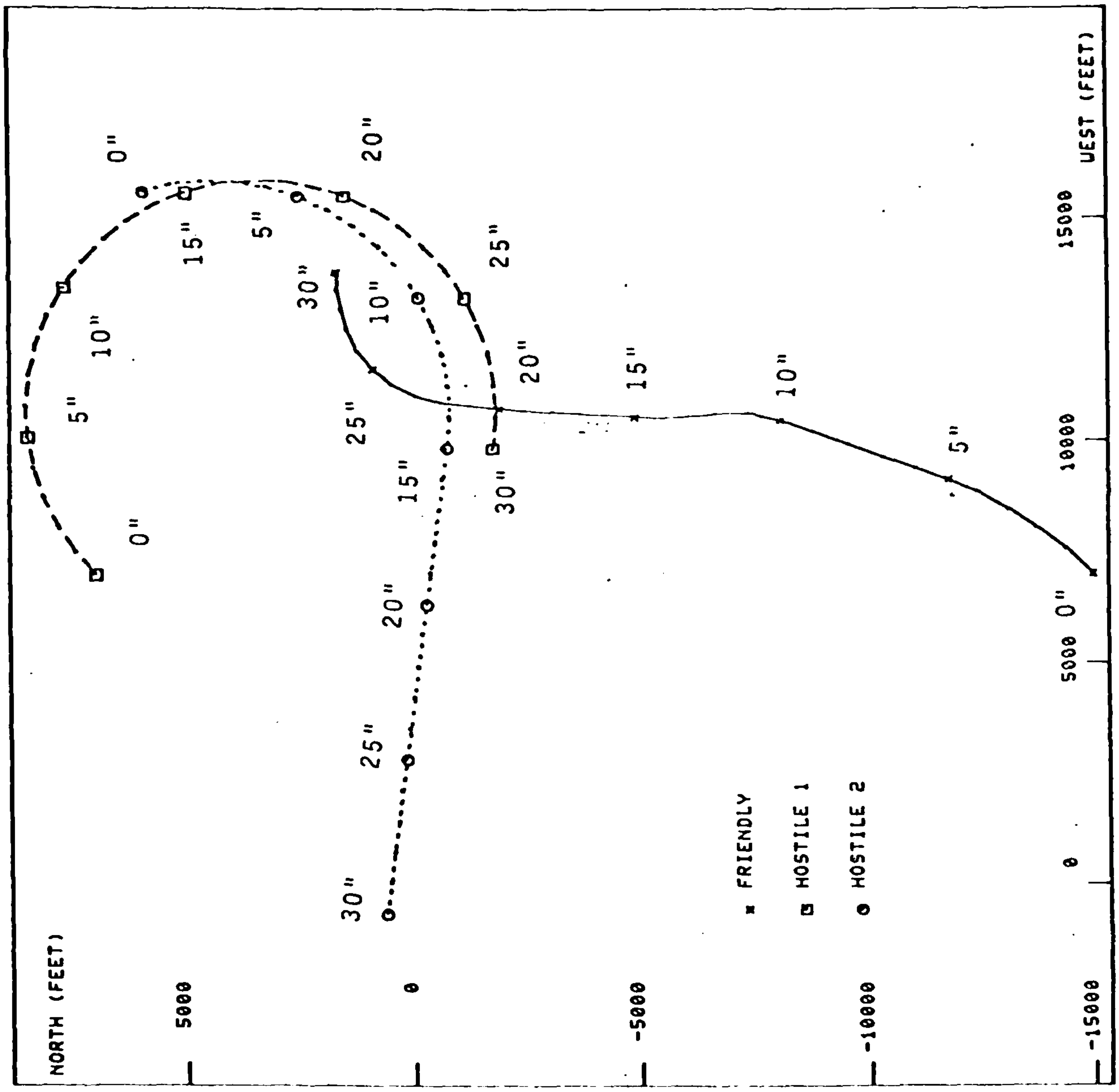
TACTICAL SITUATION AT TIME = 0.0000

1 CLASS = 1 1HOST + 2

	F TO H1	F TO H2	H1 TO F	H2 TO F	UNITS
Range	22561.0	22249.3	-	-	ft
Range Rate	-64.1	-1245.0	-	-	ft/sec
LOS Angle (LOS)	45.6	23.7	133.6	42.6	deg
LOS in Body XY Plane	-44.6	-21.4	135.0	40.9	deg
LOS in Body Z Plane	10.8	10.4	-12.8	-13.0	deg
LOS in Earth XY Plane	-45.0	-21.6	45.0	-84.2	deg
LOS in Earth Z Plane	12.8	13.0	-167.2	-167.0	deg
LOS Rate	.2	-.0	-.2	.6	deg/sec

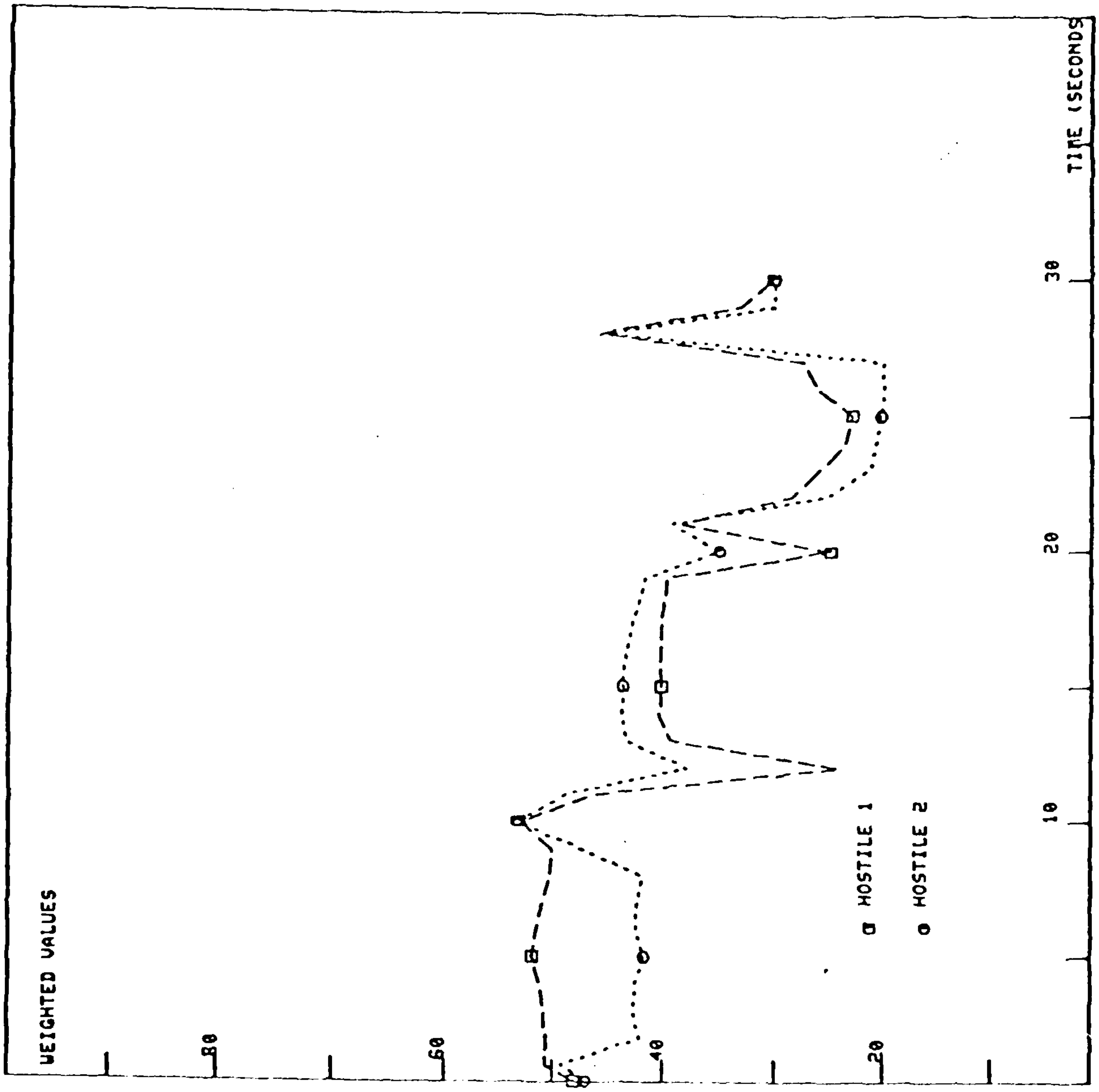
RELATIVE GEOMETRY AT ENGAGEMENT INITIATION
FOR THE FIRST TWO SAMPLE ENGAGEMENTS

FIGURE 10



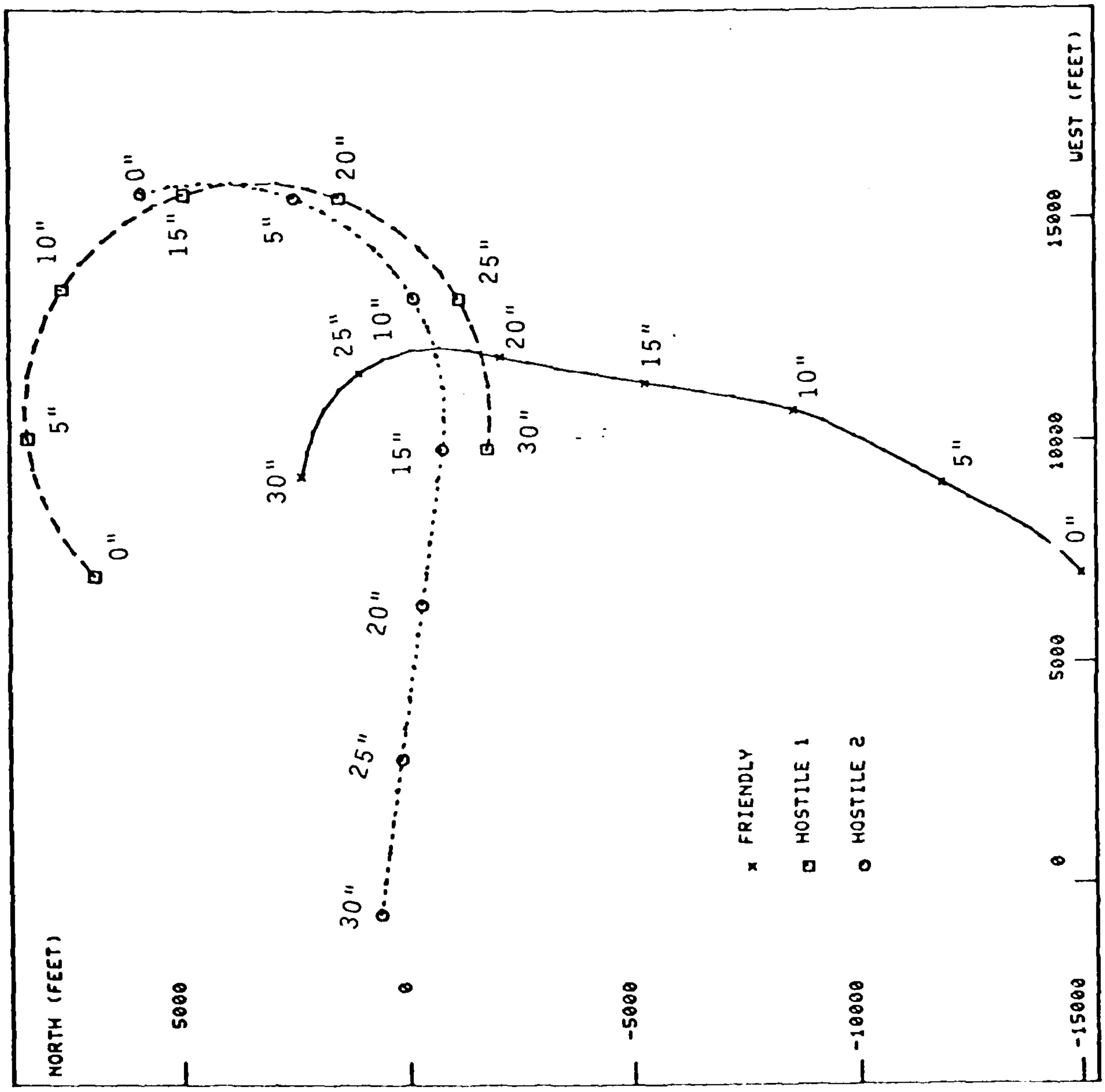
GROUND TRACE FOR SAMPLE ENGAGEMENT 1
(CONSERVATIVE PILOT)

FIGURE 11



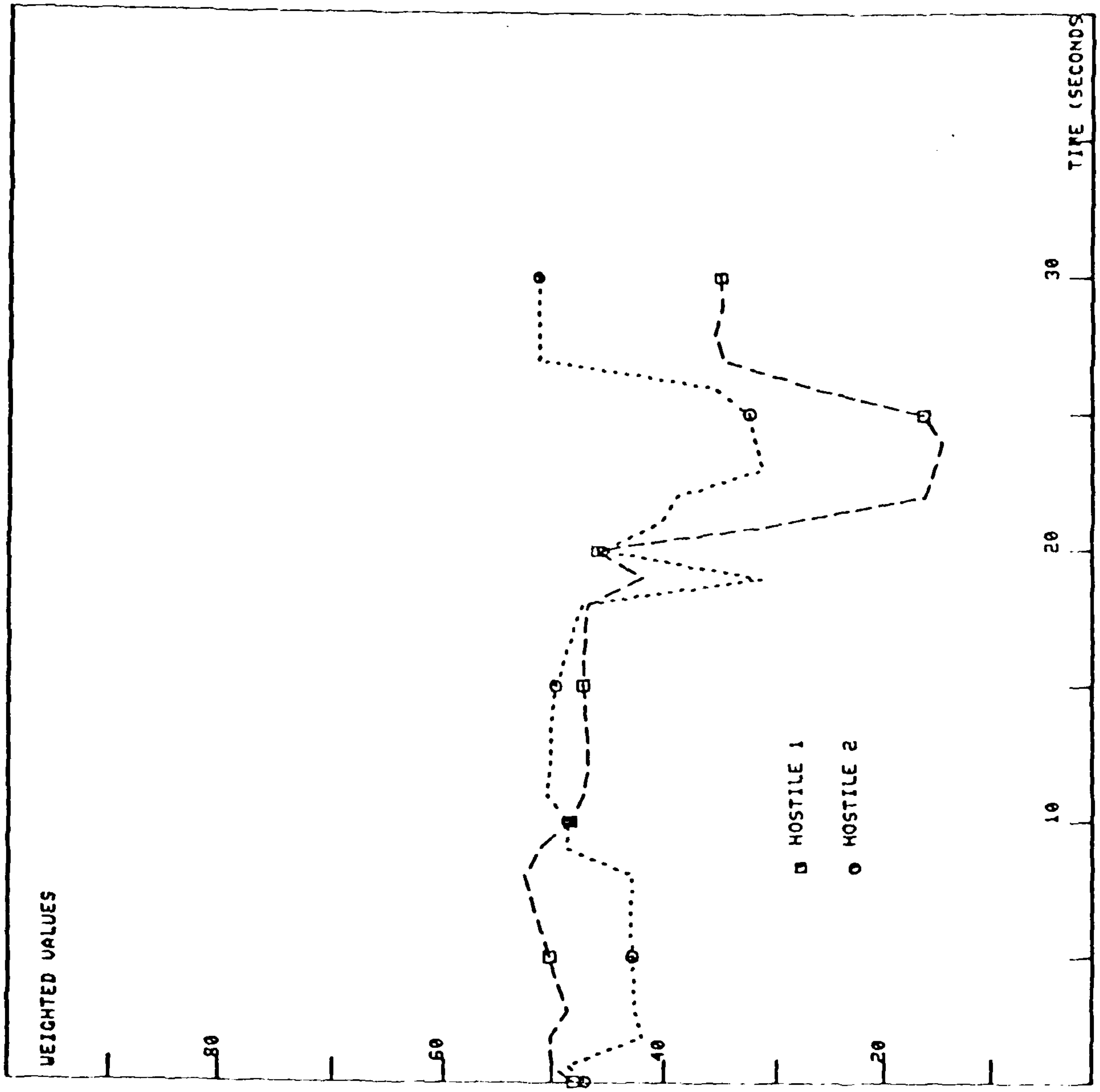
WEIGHTED VALUES FOR FRIENDLY'S VALUATED
STATE SPACE WITH RESPECT TO HOSTILE 1
AND HOSTILE 2 SEPARATELY (ENGAGEMENT 1)

FIGURE 12



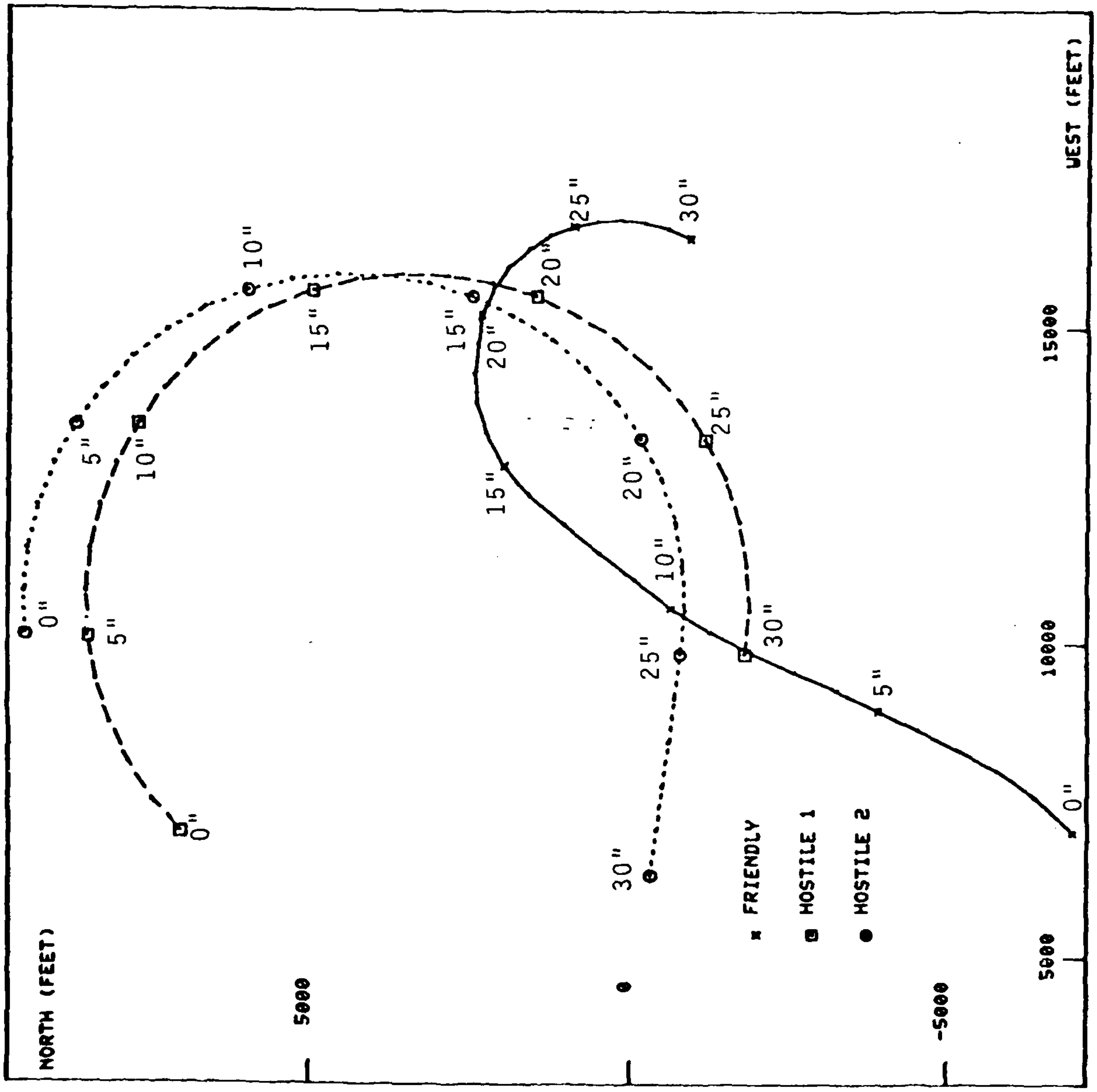
GROUND TRACE FOR SAMPLE ENGAGEMENT 2
(AGGRESSIVE PILOT)

FIGURE 13



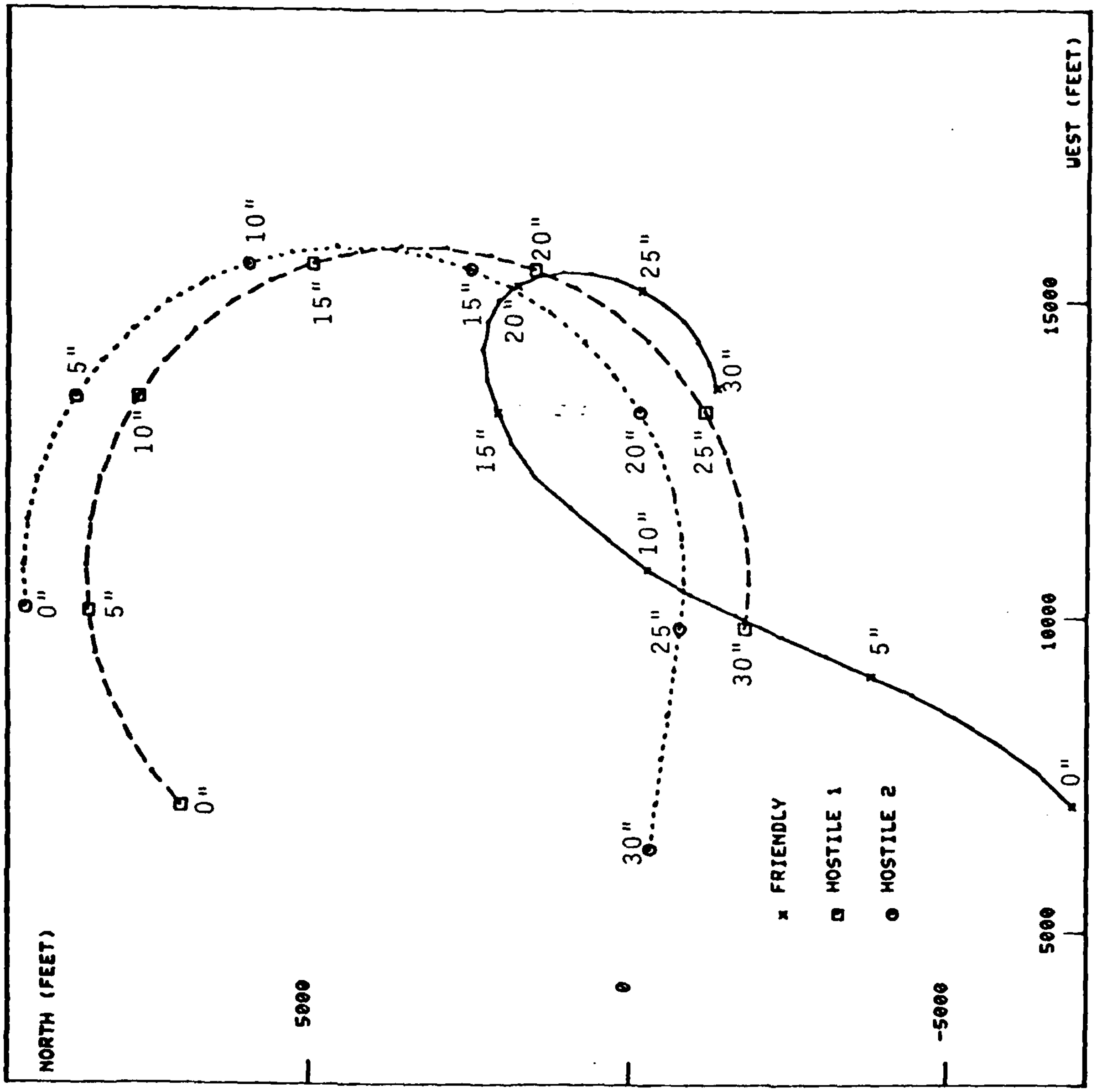
WEIGHTED VALUES FOR FRIENDLY'S VALUATED
STATE SPACE WITH RESPECT TO HOSTILE 1
AND HOSTILE 2 SEPARATELY (ENGAGEMENT 2)

FIGURE 14



GROUND TRACE OF EXAMPLE 3
(FRIENDLY A/C = F-4)

FIGURE 15



GROUND TRACE OF EXAMPLE 4
(FRIENDLY AIRCRAFT = F-14)

FIGURE 16

APPENDIX A

PRINTOUT OF INPUT DATA

SPEED OF SOUND (FEET/SEC)

TABLE HAS 121 POINTS, ALTITUDE INCREMENT IS 500 FEET, ALTITUDE REGIME IS ZERO TO 60,000 FEET.

1116.45	1114.53	1112.61	1110.68	1108.75	1106.81	1104.88	1102.94	1100.99	1099.05	0 TO 4500 FEET
1097.10	1095.14	1093.19	1091.22	1089.26	1087.29	1085.32	1083.35	1081.37	1079.39	5000 TO 9500 FEET
1077.40	1075.42	1073.42	1071.43	1069.43	1067.43	1065.42	1063.41	1061.39	1059.38	10000 TO 14500 FEET
1057.36	1055.33	1053.30	1051.27	1049.23	1047.19	1045.15	1043.10	1041.05	1038.99	15000 TO 19500 FEET
1036.93	1034.86	1032.80	1030.72	1028.65	1026.57	1024.48	1022.39	1020.30	1018.20	20000 TO 24500 FEET
1016.10	1014.00	1011.89	1009.77	1007.65	1005.53	1003.40	1001.27	999.14	996.99	25000 TO 29500 FEET
994.85	992.70	990.55	988.39	986.22	984.05	981.88	979.70	977.52	975.34	30000 TO 34500 FEET
973.14	971.83	969.74	968.08	968.08	968.08	968.08	968.08	968.08	968.08	35000 TO 39500 FEET
968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	40000 TO 44500 FEET
968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	45000 TO 49500 FEET
968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	50000 TO 54500 FEET
968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	968.08	55000 TO 59500 FEET
968.08										60000 FEET

AIR DENSITY, RHOD, SLUGS /FT CUBED, AS A FUNCTION OF ALTITUDE

TABLE HAS 121 POINTS, ALTITUDE INCREMENT IS 500 FEET, ALTITUDE REGIME IS ZERO TO 60,000 FEET.

.0023768	.0023423	.0023081	.0022743	.0022408	.0022078	.0021751	.0021428	.0021109	.0020793	0 TO 4500 FEET
.0020481	.0020173	.0019868	.0019567	.0019269	.0018975	.0018684	.0018397	.0018113	.0017832	5000 TO 9500 FEET
.0017555	.0017281	.0017011	.0016743	.0016479	.0016218	.0015961	.0015706	.0015455	.0015206	10000 TO 14500 FEET
.0014961	.0014719	.0014480	.0014244	.0014010	.0013780	.0013553	.0013328	.0013107	.0012888	15000 TO 19500 FEET
.0012672	.0012459	.0012249	.0012041	.0011837	.0011634	.0011434	.0011237	.0011043	.0010851	20000 TO 24500 FEET
.0010662	.0010475	.0010291	.0010110	.0009931	.0009754	.0009580	.0009408	.0009238	.0009071	25000 TO 29500 FEET
.0008906	.0008744	.0008584	.0008426	.0008270	.0008117	.0007965	.0007816	.0007669	.0007524	30000 TO 34500 FEET
.0007382	.0007241	.0007102	.0006944	.0006780	.0006619	.0006463	.0006310	.0006160	.0006015	35000 TO 39500 FEET
.0005872	.0005733	.0005595	.0005465	.0005336	.0005210	.0005087	.0004966	.0004849	.0004734	40000 TO 44500 FEET
.0004622	.0004513	.0004406	.0004302	.0004200	.0004101	.0004004	.0003909	.0003817	.0003727	45000 TO 49500 FEET
.0003639	.0003553	.0003469	.0003387	.0003307	.0003229	.0003152	.0003078	.0003005	.0002934	50000 TO 54500 FEET
.0002865	.0002797	.0002731	.0002666	.0002603	.0002542	.0002482	.0002423	.0002366	.0002310	55000 TO 59500 FEET
.0002256										60000 FEET

REFERENCE AREA 530.0 SQFT

MAXIMUM LOAD FACTOR(AFTERBURNER-ON) F4VG(G)

ALTITUDE \ MACH NO	.20	.50	.80	.90	1.00	1.10	1.20	1.50	1.80	2.00	2.20	2.40
0.	1.0	4.2	7.0	7.0	6.6	6.2	6.0	6.0	1.0	0.0	0.0	0.0
15000.	.5	4.0	6.0	6.8	6.3	6.3	6.3	6.0	1.0	0.0	0.0	0.0
30000.	.4	1.5	3.3	4.3	5.4	6.3	6.4	6.4	6.4	0.0	0.0	0.0
45000.	.2	.8	1.8	2.3	2.8	3.2	3.7	4.6	4.7	5.0	0.0	0.0
55000.	.1	.5	.9	1.3	1.5	1.8	2.5	3.8	3.8	4.0	0.0	0.0

SUSTAINED LOAD FACTOR(AFT BURN-ON) F4SG (G)

ALTITUDE \ MACH NO	.20	.50	.80	.90	1.00	1.10	1.20	1.50	1.80	2.00	2.20	2.40
0.	.6	3.6	6.4	6.9	6.2	2.4	0.0	0.0	0.0	0.0	0.0	0.0
15000.	.4	2.1	4.0	4.4	4.5	4.2	3.9	0.0	0.0	0.0	0.0	0.0
30000.	.2	1.2	2.2	2.5	2.6	2.7	2.8	2.6	1.1	0.0	0.0	0.0
45000.	.1	.6	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.0	0.0	0.0
55000.	.1	.3	.6	.7	.8	.6	.9	.9	.9	.6	0.0	0.0

THRUST TABLES FOR 1/2 OF PLANE S ENGINES

IDLE THRUST TIDLE (LB)

MACH NO \ ALTITUDE	0.	10000.	20000.	30000.	40000.	50000.	60000.
.2	30.	100.	140.	175.	260.	320.	340.
.4	-240.	-140.	-50.	90.	220.	320.	390.
.6	-570.	-440.	-270.	-70.	140.	270.	350.
.8	-1030.	-800.	-540.	-270.	-10.	170.	280.
.9	-1420.	-1010.	-670.	-370.	-90.	110.	240.
1.0	-1620.	-1200.	-820.	-480.	-170.	60.	200.
1.1	-950.	-1450.	-950.	-600.	-250.	0.	160.
1.2	1500.	-1650.	-1120.	-710.	-360.	-60.	120.
1.4	3450.	2300.	-1370.	-900.	-520.	-180.	30.
1.6	1600.	3320.	2570.	-1000.	-660.	-330.	-50.
1.8	-1950.	-1000.	2620.	2840.	250.	0.	0.
2.0	-2940.	-2740.	-1900.	2700.	2550.	1600.	980.
2.2	-3000.	-3000.	-2950.	-140.	1150.	780.	480.
2.4	-3000.	-3000.	-3000.	-1700.	-500.	-270.	-150.

MACH NO	ALTITUDE 0.	10000.	20000.	30000.	40000.	50000.	60000.
.2	4650.	7070.	4720.	3080.	1800.	1010.	600.
.4	9660.	7310.	5010.	3290.	1980.	1160.	720.
.6	9720.	7690.	5480.	3590.	2230.	1340.	800.
.8	10190.	8240.	6110.	4120.	2580.	1550.	900.
.9	10560.	8600.	6470.	4450.	2790.	1690.	990.
1.0	10810.	8940.	6830.	4740.	3080.	1860.	1060.
1.1	10760.	9310.	7240.	5140.	3430.	2100.	1175.
1.2	9970.	9680.	7680.	5530.	3780.	2280.	1140.
1.4	8300.	9960.	8450.	6300.	4390.	2620.	1050.
1.6	6930.	9180.	8820.	7000.	4880.	2900.	940.
1.8	5780.	8330.	9095.	6890.	5030.	2990.	800.
2.0	4630.	6460.	7370.	6780.	5180.	3080.	570.
2.2	3350.	4300.	5200.	5400.	4030.	2450.	320.
2.4	2330.	2450.	3450.	4450.	3290.	2000.	0.

AFTERBURNER THRUST TAB (LB)

MACH NO	ALTITUDE 0.	10000.	20000.	30000.	40000.	50000.	60000.
.2	15630.	11380.	7700.	4880.	2550.	1170.	600.
.4	16600.	11900.	8200.	5500.	3060.	1600.	700.
.6	16700.	13000.	9300.	6200.	3750.	2200.	1100.
.8	18700.	14800.	11070.	7600.	4800.	2900.	1400.
.9	20000.	15960.	12150.	8350.	5400.	3200.	1700.
1.0	21350.	17200.	13400.	9300.	5900.	3600.	2000.
1.1	19660.	18750.	14500.	10500.	6600.	4000.	2300.
1.2	19420.	20300.	15700.	11600.	7300.	4500.	2700.
1.4	19150.	21200.	18300.	13600.	9000.	5600.	3300.
1.6	18600.	20920.	20300.	15600.	10800.	6600.	4000.
1.8	17750.	19900.	21100.	17300.	12400.	7700.	4500.
2.0	16900.	18850.	19450.	18200.	13400.	8200.	5100.
2.2	13500.	15100.	16350.	17500.	12150.	7300.	5700.
2.4	12100.	12500.	14600.	17400.	11900.	7000.	6300.

LIFT COEFF / MACH NO	.2	.5	.8	.9	1.0	1.1	1.2	1.5	1.8	2.0
0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
.1	.0297	.0302	.0295	.0283	.0279	.0279	.0300	.0387	.0562	.0794
.2	.0593	.0604	.0590	.0565	.0559	.0559	.0600	.0775	.1124	.1588
.3	.0890	.0906	.0885	.0848	.0838	.0838	.0901	.1162	.1686	.2382
.4	.1187	.1208	.1180	.1131	.1117	.1117	.1201	.1550	.2248	.3176
.5	.1484	.1510	.1475	.1414	.1396	.1396	.1501	.1937	.2810	.3971
.6	.1780	.1812	.1770	.1696	.1676	.1676	.1801	.2325	.3372	.4765
.7	.2077	.2114	.2065	.1979	.1955	.1955	.2101	.2712	.3934	.5559
.8	.2374	.2416	.2360	.2262	.2234	.2234	.2402	.3100	.4496	.6353
.9	.2670	.2717	.2655	.2545	.2513	.2513	.2702	.3487	.5058	0.0000
1.0	.2967	.3019	.2950	.2827	.2793	.2793	.3002	.3875	.5620	0.0000
1.1	.3264	.3321	.3245	.3110	.3072	.3072	.3302	.4262	.6182	0.0000
1.2	.3560	.3623	.3540	.3393	.3351	.3351	.3602	.4650	.6744	0.0000
1.3	.3857	.3925	.3834	.3676	.3630	.3630	.3903	.5037	0.0000	0.0000
1.4	.4154	.4227	.4129	.3958	.3910	.3910	.4203	.5424	0.0000	0.0000
1.5	.4451	.4529	.4424	.4241	.4189	.4189	.4503	.5812	0.0000	0.0000
1.6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

CL SUP ALPHA   F4CLA (FOR NEG. CL)

MACH NO	.2	.5	.8	.9	1.0	1.1	1.2	1.5	1.8	2.0
	3.3703	3.3119	3.3903	3.5368	3.5810	3.5810	3.3311	2.5809	1.7794	1.2592

LIFT COEFF	MACH NO .2	.5	.8	.9	1.0	1.1	1.2	1.5	1.8	2.0
0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
.1	.0297	.0302	.0295	.0283	.0279	.0279	.0300	.0387	.0562	.0794
.2	.0593	.0604	.0590	.0565	.0559	.0559	.0600	.0775	.1124	.1588
.3	.0890	.0906	.0885	.0848	.0838	.0838	.0901	.1162	.1686	.2382
.4	.1187	.1208	.1180	.1131	.1117	.1117	.1201	.1550	.2248	.3176
.5	.1484	.1510	.1475	.1414	.1396	.1396	.1501	.1937	.2810	.3971
.6	.1780	.1812	.1770	.1696	.1676	.1676	.1801	.2325	.3372	.4765
.7	.2077	.2114	.2065	.1979	.1955	.1955	.2101	.2712	.3934	.5559
.8	.2374	.2416	.2360	.2262	.2234	.2234	.2402	.3100	.4496	.6353
.9	.2670	.2717	.2655	.2545	.2513	.2513	.2702	.3487	.5058	0.0000
1.0	.2967	.3019	.2950	.2827	.2793	.2793	.3002	.3875	.5620	0.0000
1.1	.3264	.3321	.3245	.3110	.3072	.3072	.3302	.4262	.6182	0.0000
1.2	.3560	.3623	.3540	.3393	.3351	.3351	.3602	.4650	.6744	0.0000
1.3	.3857	.3925	.3834	.3676	.3630	.3630	.3903	.5037	0.0000	0.0000
1.4	.4154	.4227	.4129	.3958	.3910	.3910	.4203	.5424	0.0000	0.0000
1.5	.4451	.4529	.4424	.4241	.4189	.4189	.4503	.5812	0.0000	0.0000
1.6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

CL SUP ALPHA   FSCLA (FOR NEG. CL)

MACH NO	.2	.5	.8	.9	1.0	1.1	1.2	1.5	1.8	2.0
	3.3703	3.3119	3.3903	3.5368	3.5810	3.5810	3.3311	2.5809	1.7794	1.2592

LIFT COEFF \ MACH NO	.2	.5	.8	.9	1.0	1.1	1.2	1.5	1.8	2.0
0.0	.0200	.0200	.0199	.0226	.0300	.0344	.0367	.0388	.0388	.0388
.1	.0212	.0212	.0211	.0245	.0320	.0369	.0389	.0424	.0424	.0424
.2	.0248	.0248	.0249	.0295	.0370	.0424	.0454	.0504	.0525	.0539
.3	.0314	.0314	.0329	.0359	.0454	.0534	.0569	.0654	.0714	.0747
.4	.0415	.0417	.0449	.0495	.0610	.0689	.0749	.0887	.1004	.1063
.5	.0579	.0587	.0649	.0724	.0829	.0919	.1009	.1209	.1409	.1679
.6	.0869	.0879	.0949	.1044	.1159	.1264	.1359	.1692	.2149	.2479
.7	.1299	.1312	.1409	.1519	.1679	.1814	.1979	.2434	.2979	.3279
.8	.1815	.1825	.1934	.2050	.2310	.2469	.2689	.3302	.3849	.4099
.9	.2149	.2159	.2464	.2619	.2929	.3109	.3389	.4142	.4689	.4909
1.0	.2889	.2902	.3009	.3199	.3564	.3734	.4089	.4999	.5539	.5739
1.1	.3275	.3297	.3400	.3645	.4025	.4055	.4280	.6040	.5605	.5905
1.2	.3805	.3805	.3900	.4185	.4635	.4645	.4895	.6915	.6275	.6605
1.3	.4335	.4312	.4400	.4725	.5245	.5235	.5510	.7790	.6945	.7305
1.4	.4865	.4820	.4900	.5265	.5855	.5825	.6125	.8665	.7615	.8005
1.5	.5395	.5327	.5400	.5805	.6465	.6415	.6740	.9540	.8285	.8705
1.6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

CD (WITH HI LIFT DEVICES)   FSCOR

LIFT COEFF \ MACH NO	.2	.5	.8	.9	1.0	1.1	1.2	1.5	1.8	2.0
0.0	.0200	.0200	.0199	.0226	.0300	.0344	.0367	.0388	.0388	.0388
.1	.0212	.0212	.0211	.0245	.0320	.0369	.0389	.0424	.0424	.0424
.2	.0248	.0248	.0249	.0295	.0370	.0424	.0454	.0504	.0525	.0539
.3	.0314	.0314	.0329	.0359	.0454	.0534	.0569	.0654	.0714	.0747
.4	.0415	.0417	.0449	.0495	.0610	.0689	.0749	.0887	.1004	.1063
.5	.0579	.0587	.0649	.0724	.0829	.0919	.1009	.1209	.1409	.1679
.6	.0869	.0879	.0949	.1044	.1159	.1264	.1359	.1692	.2149	.2479
.7	.1299	.1312	.1409	.1519	.1679	.1814	.1979	.2434	.2979	.3279
.8	.1815	.1825	.1934	.2050	.2310	.2469	.2689	.3302	.3849	.4099
.9	.2149	.2159	.2464	.2619	.2929	.3109	.3389	.4142	.4689	.4909
1.0	.2889	.2902	.3009	.3199	.3564	.3734	.4089	.4999	.5539	.5739
1.1	.3275	.3297	.3400	.3645	.4025	.4055	.4280	.6040	.5605	.5905
1.2	.3805	.3805	.3900	.4185	.4635	.4645	.4895	.6915	.6275	.6605
1.3	.4335	.4312	.4400	.4725	.5245	.5235	.5510	.7790	.6945	.7305
1.4	.4865	.4820	.4900	.5265	.5855	.5825	.6125	.8665	.7615	.8005
1.5	.5395	.5327	.5400	.5805	.6465	.6415	.6740	.9540	.8285	.8705
1.6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

MACH NO	.2	.4	.6	.8	.9	1.0	1.1	1.2	1.4	1.6	1.8	2.0	2.2	2.4
	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.30	1.10	.80	.60	.40	.20

MIN AND MAX MACH NUMBERS F4MMI,F4MMA

ALTITUDE	M-MIN	M-MAX
0.	.20	1.20
5000.	.23	1.30
10000.	.27	1.40
15000.	.30	1.50
20000.	.34	1.63
25000.	.38	1.77
30000.	.42	1.90
35000.	.51	1.97
40000.	.61	2.04
45000.	.71	2.10
50000.	.75	2.10
55000.	.80	2.10
60000.	2.00	2.00

DIVE RECOVERY ANGLE RECANG

ALTITUDE / MACH NO	.20	.50	.80	.90	1.00	1.10	1.20	1.50	1.80	2.00	2.20	2.40
0.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5000.	1.5708	1.5708	.7854	.5236	.4712	.4363	.4189	.3316	.2967	.2618	.2618	.2618
10000.	1.5708	1.5708	1.5708	1.0472	.9250	.8552	.8203	.6458	.5760	.5236	.5236	.5236
15000.	1.5708	1.5708	1.5708	1.5708	1.3963	1.2741	1.2217	.9599	.8727	.7854	.7854	.7854
20000.	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.3439	1.1519	.9948	.8901	.8901	.8901
25000.	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.4486	1.2915	1.0996	.9948	.9948	.9948
30000.	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.4312	1.2043	1.0996	1.0996	1.0996
35000.	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.3090	1.1868	1.1868	1.1868
40000.	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.3788	1.3788	1.3788
45000.	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708	1.5708

SPEED BRAKE DRAG COEFF(FULL DEFLECTION) SPCDR

MACH NO	.2	.4	.6	.8	.9	1.0	1.1	1.2	1.4	1.6	1.8	2.0	2.2	2.4

0.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.0000

AIRCRAFT WEIGHT = 42000.0 LBS

WEAPONS (FRIENDLY) 20.0

XEF	YEF	HF	VELF	PSIF	THETF	PHIF
-15000.00	7000.00	15000.00	600.000	45.000	0.000	0.000

FSTRGF = +1 STRAIGHT FLIGHT, BELLY DOWN
FSTRGF = -1 STRAIGHT FLIGHT, BELLY UP
FSTRGF = 0 TURN INTO A MANEUVER PLANE
DTPRF = TIME BETWEEN TARGET TACTICAL DECISIONS
TIMFPF = FRIENDLY FORWARD PREDICTION TIME

FSTRGF	GLEVLF	TPRSF	DTPRF	TIMFPF	FNTILF
1.000	1.000	2.000	1.000	3.000	8.000

HOSTILE 1 INITIAL CONDITIONS

XEH(1)= 7000.00 YEH(1)= 7000.00 H(1)= 20000.00

XEDOTH(1)= 500.00 YEDOTH(1)= 500.00 HDOT(1)= 0.00

PSIH(1)= 45.00 THETAH(1)= 0.00 PHIH(1)= 0.00

HOSTILE 2 INITIAL CONDITIONS

XEH(2)= 4904.20 YEH(2)= 15593.94 H(2)= 20000.00

XEDOTH(2)= -674.65 YEDOTH(2)= 213.69 HDOT(2)= 0.00

PSIH(2)= 162.41 THETAH(2)= 0.00 PHIH(2)= 0.00

TBEGN = START TIME OF SIMULATION
TEND = STOP TIME OF SIMULATION
DT = INTEGRATION STEPSIZE
FKPR = TIME STEPS BETWEEN PRINTOUTS
FKAPR = PRINT-SUPPRESS FLAG
FKTAP = TAPE INTERVAL (NEGATIVE FOR NO TAPE)

PROGRAM CONTROL DATA

TBEGN	TEND	DT	FKPR	FKAPR	FKTAP
0.000	5.000	.06250	16.00	0.00	-1.00

CLASS	1	2	3	4	5	6	7	8	9
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
9	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
10	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
11	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
24	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

CLASS	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
13	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
14	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
16	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
17	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
18	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
20	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
21	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
22	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
23	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
24	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

CLASS	1	2	3	4	5	6	7	8	9
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
9	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
10	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
11	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
12	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
13	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
14	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
16	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
17	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
18	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
20	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
21	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
22	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
23	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
24	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

ATKR SUBJECT TO BLACK-OUT

TRGT SUBJECT TO BLACK-OUT

DAT
ILM